

SPECIAL **TIME** EDITION

100 New Scientific Discoveries

Fascinating, Momentous and Mind-Expanding Breakthroughs



THE EARTH



ZOOLOGY



TECHNOLOGY



MEDICINE

SPECIAL **TIME** EDITION

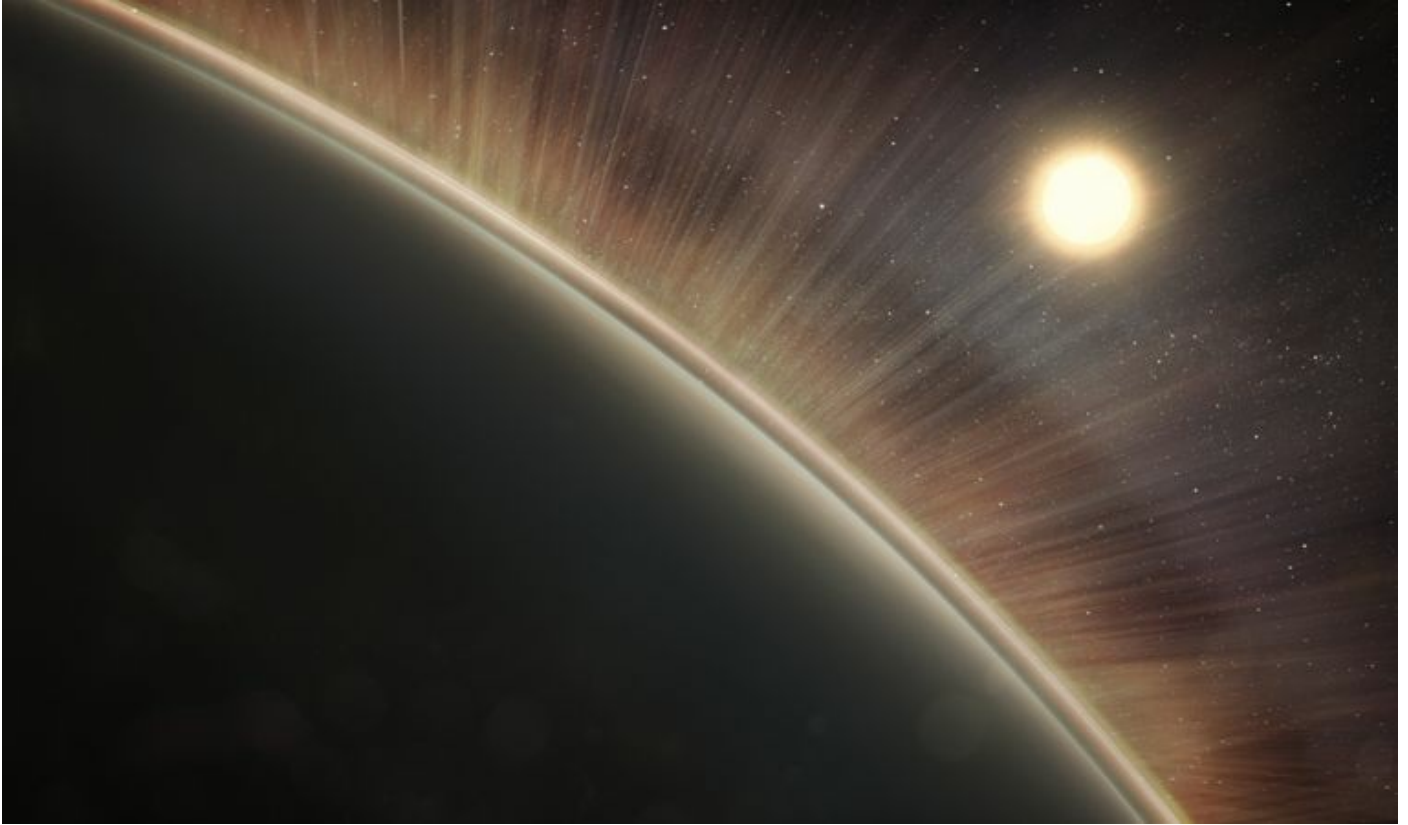
100 New Scientific Discoveries

Fascinating, Momentous and Mind-Expanding Breakthroughs



Many majesties of nature come together in Iceland.

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Electric winds on Venus may have stripped Earth's twin of its oceans.

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Parts of this book were previously published in TIME and on Time.com.

INTRODUCTION

There's No Such Thing as a Final Frontier

BY JEFFREY KLUGER



Try as hard as you want, you'll never master science. No one ever has. Einstein? Galileo? Darwin? Curie? Please. Einstein may have nailed physics, but try getting him to talk botany. Galileo, Darwin and Curie wouldn't have lasted five minutes in a meteorology class. That's the way it is with science. Start to list the major scientific disciplines, and you have to get through astronomy, agronomy, anthropology and archaeology before you even approach the *Bs*. The best any scientist can hope to do is to grasp a tiny portion of a single field and then look for how it bumps into other areas of science—the way chemistry becomes organic chemistry, which then rolls into biology; the way astronomy and physics crash and fuse in the collision of two black holes that proves the existence of gravitational waves.

And what about the rest of us, the non-scientists? What's the best we can do if we want to wrap our minds around the great sprawl of studies that emerge every day of every year? The first thing to know is not to wait for the eureka moments. Yes, every year there will be studies that command our attention more than others, but science usually progresses more incrementally. Being alert to the breakthroughs that don't shake the

world—but do shape it—is important.

It's impossible to know what the impact will be of the 100 breakthroughs in 10 scientific disciplines that are documented in these pages. Some, like the gene-editing technique known as CRISPR, are already affecting us, with human trials under way that use the technology. Other discoveries, like the unearthing of bones belonging to a possibly new human ancestor, will have a slower, subtler influence. Either way, the breakthroughs will keep coming, in discipline after discipline, year after year.

The ones we write about in these pages are just the latest in that constant, thrilling churn.

Technology

A Wearable Pancreas ■ Robotic Deliveries ■ iPads as Anesthetic ■ Underwater Wearables ■
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The Bionic Pancreas Is Almost a Reality

A father's mission to invent a groundbreaking device that will change diabetes forever

BY ALEXANDRA SIFFERLIN



The inventor of the device, Ed Damiano, with his diabetic son, David

In the summer of 2015, 15-year-old David Damiano spent more than 24 hours away from his parents for the first time in his life. He went to summer camp, but it was hardly the same experience most kids get to enjoy. David, like 1.25 million other Americans, has Type 1 diabetes, which means that his life depends on constantly tracking and precisely adjusting his blood sugar. If it's too high, he feels nauseated and has to inject himself with insulin through a pump attached to his body. If it's too low, he becomes delirious and shaky and needs to eat something high in carbohydrates—fast.

Even when he's not feeling symptoms, he has to continually tweak his insulin levels up or down because if they aren't stable, he's at risk for an emergency-room visit and long-

term consequences ranging from blindness to kidney failure to amputations. All of us require the same nonstop insulin adjustments. But for most of us, the job is done automatically by a pancreas that works properly. David doesn't have one of those.

A few days after he started camp, David awoke feeling angry—the disease can toy with your hormones—and sick to his stomach. His blood sugar was high, and he realized his insulin pump wasn't working. After frantically calling his dad at 1:30 a.m., David fitted himself with a backup pump. “I definitely could do camp again, but I'm not sure I'm willing,” he says. “It's just hard.”

What David and other diabetics need is something that automates the moment-to-moment monitoring that can suck so much of the joy out of life. Any child's parents would wish for such a solution—but David's are in a position to help design it. His mother, Toby Milgrome, is a pediatrician who diagnosed her son's condition when he was 11 months old. His father, Ed Damiano, a professor of biomedical engineering at Boston University, has made it his mission to build a portable, wearable bionic pancreas, a device he hopes to have on the market as early as 2017, the year David is set to go off to college.

A device like this will change lives and could also translate into profits for Damiano. Type 1 diabetes accounts for \$5 billion in health-care costs each year—which is why a number of research groups are working on their own versions of the bionic pancreas.

In September 2016, a similar device, called Mini-Med 670G, was approved by the Food and Drug Administration, although it works differently from Damiano's prototype. This device requires people who have it to manually enter information when they eat carbohydrates as well as entering their blood glucose level. Researchers hope there will ultimately be an approved device that takes out that manual work, too.

Damiano is convinced he can bring his bionic pancreas to market soon. Already about 260 people with diabetes have tried a form of the device in clinical trials, and the experience has been transformative for them. At the end of one recent trial, an 11-year-old boy said he liked the bionic pancreas so much that he ran away from the researchers conducting the test, and it took them over an hour to get the device back.

When David was 11 months old, his mother noticed that in the span of one week, her once vivacious son became lethargic. He lost weight, developed an insatiable thirst and burst his diaper from urinating so much. At the end of the week, Milgrome took him into her office for lab work. “I knew it was nothing simple at that point,” she recalls. “I had brain tumor, leukemia and diabetes on my mind.” David's blood sugar was 800 milligrams per deciliter—normal is 70 to 120—and a diagnosis of diabetes was confirmed. Milgrome rushed David to the hospital and spent the night curled up with him. The best scenario was that he would survive but live a radically different life than his parents had expected.

The vast majority of people with diabetes monitor their blood sugar by pricking themselves with a needle 10 or more times a day and squeezing a drop of blood onto a sensor strip. If they need insulin, they must slip away somewhere private and inject themselves with a syringe. Some diabetics, like David, use an insulin pump and a

continuous glucose monitor (CGM), both of which are attached to the body on the lower stomach. The CGM checks blood sugar every five minutes and beeps an alert if levels are too high or too low. The pump must then be operated manually.

Damiano has modified his son's system, devising a way to hack David's CGM so it uploads his blood sugar readings to the cloud—a way of keeping an eye on him when they aren't together. Still, about 20 times a day, David's monitor issues a loud beep, and no matter where he is, he must manually adjust his insulin dose.

CGMs and pumps are certainly an improvement over the needle-and-syringe protocol, but only 25% of people with diabetes opt for that higher-tech route. Insurance typically covers the insulin pump, but not always. A pump costs about \$6,500 on its own and has separate costs for pieces like insulin cartridges and reservoirs, all of which add up to about \$1,500 a year out of pocket. A CGM costs \$500 to \$1,000 for the device, and it's about \$50 to \$100 every week for the replaceable sensor needle that sits under the skin. CGMs are not covered by Medicare nor, in most states, are they covered by Medicaid.

Within months of David's diagnosis in 2000, Damiano decided it was time to change the game. At the time, he oversaw a staff of scientists and graduate students at the University of Illinois at Urbana-Champaign studying the mathematical models of bodily systems, like the flow of fluids in the ear involved in balance. But the bionic-pancreas idea had been teasing at him ever since David got sick. He put one of his graduate students, Firas El-Khatib, on the task to help him develop an algorithm for the accurate delivery of insulin and a second hormone called glucagon. With funding from diabetes-research foundations, they had a working model for experiments on pigs by late 2005.

The various generations of devices that have been tested in humans are surprisingly compact—about the size of an iPhone. Blood-sugar levels are monitored using a CGM system that relies on probes inserted into the skin. Readings are taken every five minutes, and then, depending on blood-sugar levels, a tiny pump releases insulin to bring the sugar down or glucagon to bring it back up.

The 110 people who have tried the most recent version of Damiano's device have participated in one of the four clinical trials, each more ambitious than the one before it. The bionic pancreas has worked in people ages 6 to 76 and weighing 47 to 283 pounds. The longest anyone has worn it is about 22 days.

One of Damiano's studies, written up in the *New England Journal of Medicine*, showed that 81% of people using the bionic pancreas had better blood-sugar control than with their standard treatment. For others, the bionic pancreas did not lead to better blood-sugar control. Some also felt nauseated.

Damiano started the final, pivotal trial in 2016, one that would last several months and include hundreds of participants. That study involved a far more elegant, far more portable unit, called the iLet, than the current prototype. All of the hardware is packed into a single unit that will be palm-sized and operate under a new, better algorithm that Damiano and his team are writing for an upgraded operating system.

But obstacles remain. The final pivotal clinical trial is set to conclude in 2017, and an on-market deadline for then, or close to it, leaves little wiggle room—especially in the

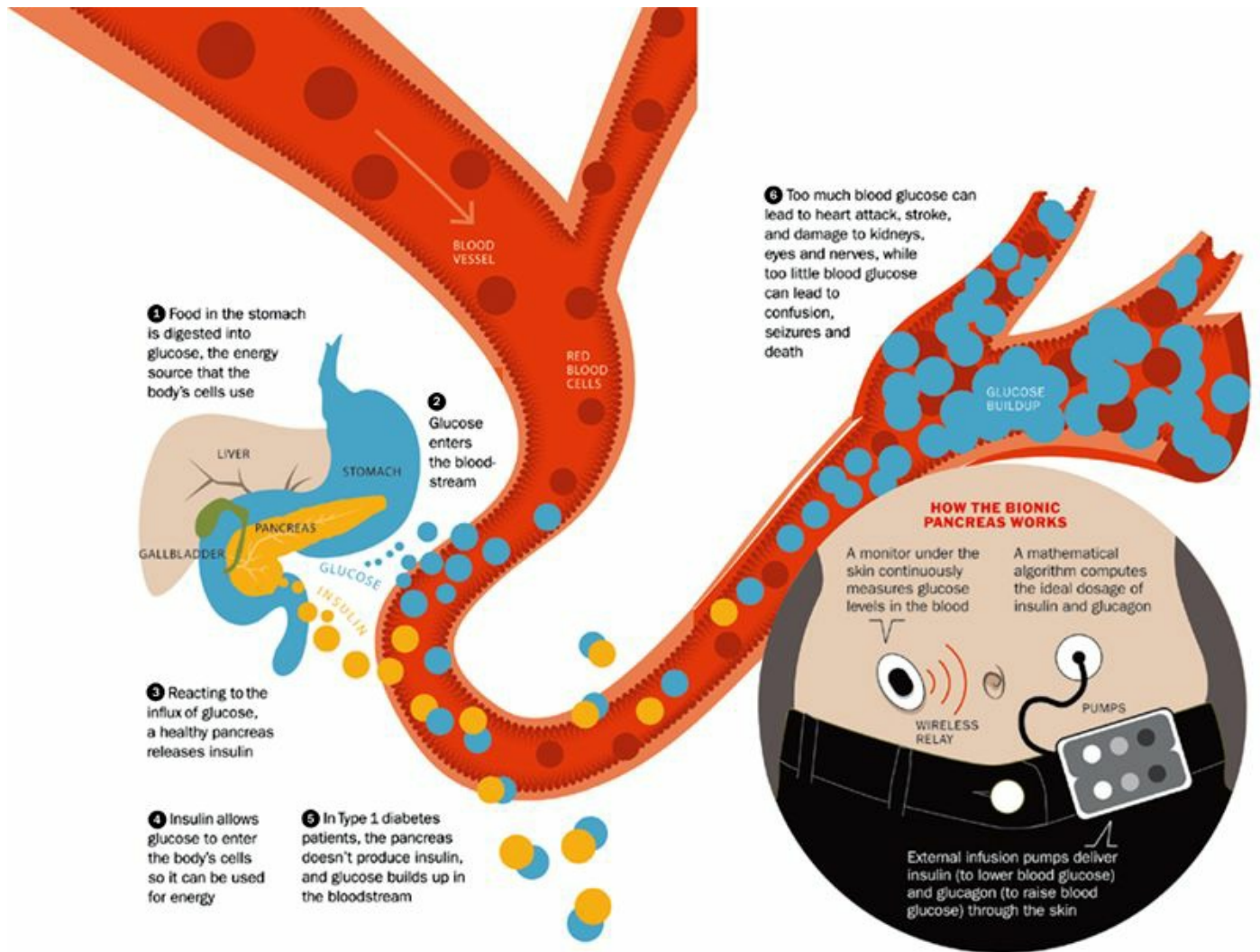
world of clinical trials, where so much can go wrong. Damiano is reaching out to the Type 1 diabetes community to help him fund the research. He thinks that kind of investment will help him meet his goal.

Proper blood-sugar control is estimated to reduce the risk of eye disease by 63%, kidney disease by 54% and nerve damage by 60% among people with diabetes. Currently, the management of Type 1, including the downstream illnesses it causes, accounts for billions of dollars in health-care costs each year. Even if the bionic pancreas can slash those costs and change patients' lives, nobody pretends it's the final answer. "I think almost everyone would agree that a cure is a medicine or therapy [a patient] could get on Day One or Two and be done," says David Harlan, who is running one of the trials, at the University of Massachusetts Medical School. "We are a long way from that." Damiano agrees. The bionic pancreas, he concedes, is "a bridge that we can keep extending until there is a cure."

For now, Damiano is especially driven to complete his work, because only when the device is approved can he offer it to the one person he most wants to help: David. Conflict-of-interest rules prevent him from trying out the device on his child before it's on the market.

David believes his father will come through. "In a way, I am very happy I was diagnosed at a young age so my dad would be inspired to do this," he says. "He's one of the only people who can do it." And if all goes well, millions of other people will have good reason to be happy too.

How the Body Uses Glucose—and What Can Go Wrong



Results from a recent study show that 81% of people using the bionic pancreas had better **blood-sugar control** than with their standard treatment

Food Is Coming to You from Robots



The future is now: Self-driving robots will soon start delivering food and groceries in certain parts of Europe. Starship Technologies has begun rolling out its six-wheeled delivery robots in London, Dusseldorf, Bern and Hamburg. The robots will be used by food delivery services and grocery stores in those areas. Starship hopes this new technology will help cut both time and costs associated with delivery.

The robots won't be autonomous to start. They will be driven remotely by Starship employees until the machines become more familiar with their delivery areas, at which point they will become almost entirely autonomous. Starship estimates that, after a while, one employee will be able to operate 100 robots at a time.

It currently costs as much as £12 (almost \$15) to have a package delivered in London. Starship wants to cut that cost down to just £1. The robots have traveled over 5,000 miles in tests, encountering more than 400,000 people. So far, no accidents have been reported.

iPads Are, in Fact, Sedatives for Kids



As many parents know, sometimes the secret to getting children to relax is simply handing them an iPad. Apparently, that move has a scientific basis. According to a small recent study, giving children who were about to undergo surgery an iPad on which to play video games was as effective at calming them down as giving them a sedative.

In the report, researchers compared the effect of using an iPad with taking a sedative called midazolam on children's anxiety before anesthesia and surgery. The researchers measured the children's anxiety at several different points throughout the day of surgery, including arrival at the hospital and when they were separated from their parents. They found that parents' and children's anxiety levels were similar between both groups, and parents were more satisfied with the experience when their child was given an iPad.

The study authors suggest that using electronic tablets could be a way to reduce stress in children without medication.

Wearables Can Now Go Underwater



One of the things that gall people who use swimming as their main form of exercise? The fitness tracker can't reliably go in the pool with them without going on the fritz. But now Fitbit is updating its popular Flex tracker for the first time since the band launched in 2013. The Fitbit Flex 2 will have a new swim-friendly design that's slimmer and can be more easily customized than its predecessor. The new model costs about \$100.

The Flex 2 is 30% smaller than the original Flex, and the tracker can be removed and placed in different types of wearable accessories. The Flex 2 is also the first Fitbit band you can actually swim with, and it's capable of automatically logging laps, duration and calories burned during water-based workouts. It's water-resistant up to 165 feet, which means it's durable enough to be used in the shower, a pool or the ocean.

The new Flex is also gaining the ability to track certain workouts without users' having to manually put the band in exercise mode. Instead, it lets you effortlessly keep tabs on your progress by viewing a series of LED lights on your wrist.

Singapore Is Getting Driverless Taxicabs



NuTonomy, a driverless car startup that spun out of the Massachusetts Institute of Technology three years ago, has its sights set on operating a fully autonomous taxi service in Singapore.

The firm, which raised \$3.6 million in seed funding, began a pilot program at One-North, a business park in downtown Singapore, in August 2016. It has already reportedly passed its first driving test, paving the way for a rollout.

The 50-person firm is facing off against a number of bigger-name rivals, such as Google, Tesla, Uber, and traditional automakers such as Ford, General Motors and Toyota, in the race to deploy autonomous vehicles.

Thanks to NuTonomy and MIT's partnership with Singapore, a country with dense urban areas that has been highly receptive to driverless car technology, the comparatively small company could become the first to operate fully self-driving cars, known as "level four," in a city commercially anywhere in the world. Google, in comparison, is testing cars rated "level three," meaning that humans are sometimes needed to take the wheel, on public roads in the U.S., though they are not as far along.

Predictions about a future in which cars will drive themselves have been a staple of science fiction, pop culture and even corporate PR for decades. But now it looks like driverless cars, at least, may finally be hitting the road.

Robot Launched to the Moon



Right around the 47th anniversary of Neil Armstrong's first steps on the moon, a spacefaring firm became the first private company to get U.S. government approval to fly a mission to the moon. "To me, going to the moon is symbolic of what individuals and small groups of people are capable of doing," says Naveen Jain, the co-founder and chairman of Moon Express.

The lunar lander is roughly the size of a go-kart, with the appearance of a juiced-up Roomba. The company's plan is to hitch a ride to low Earth orbit aboard a small rocket. The craft will then use its own engine for the 200,000-plus-mile trip onward. Once there, landing thrusters are expected to provide a smooth descent. That trip should happen sometime in 2017. To be sure, getting permission to do something and actually doing it are different—but it's a major step in the right (lunar) direction.

Virtual Reality Can Ease Pain



As trippy as it sounds, chronic pain may soon be treatable with . . . a headset. DeepStream VR, a Seattle-based virtual-reality startup, has developed a device that early research suggests can offer a reprieve from pain.

As VR technology gets better, cheaper and more accessible, a growing number of scientists and entrepreneurs are using it to treat medical conditions. The stakes are high: Goldman Sachs expects total revenue from VR to hit \$80 billion in 2025, of which more than \$5 billion could come from medical applications. With more study and research, virtual reality could one day reshape how medicine is practiced, enabling doctors to offer their patients a slew of non-invasive therapies like this one.

There's an App That May Help the Blind



Juan Pablo Ortiz, a 19-year-old programmer from Guatemala, started coding when he was just 13.

“I wanted to make an app to help blind people improve their everyday lives,” Juan Pablo Ortiz said in *Forbes*. And that’s just what he did. “It can tell you what’s on a medical prescription or what type of money you’re holding. It can even scan a person and tell you if it’s a boy or girl, approximately what age they are, and what that person is doing.”

The app, which is used by pointing it in the direction of an object, which it then identifies, is in beta testing. Before it’s ready for prime time, Ortiz wants to improve the number of things the app can identify. He said he would like to add compatibility with some type of voice assistant, such as Siri, Cortana or Google Now. If he pulls this off, it could be game-changing for the sightless.

The “Hoverboard” Revolution



Part Segway, part skateboard, the self-balancing scooter—generally known as a hoverboard, even though it doesn’t actually hover—is easily the most viral product in recent memory, drawing fans like Justin Bieber, Jimmy Fallon and Kendall Jenner.

Here’s how it works: Once someone hops onto the board, the device uses a pair of electric gyroscopes (there is one under each pad) to balance automatically, allowing users to speed forward, backward or around by slightly shifting their body weight or tilting their toes forward, backward or sideways. That enables all kinds of fun stunts, ranging from hallway races to motorized dance routines.

Maxx Yellin, the co-founder of PhunkeeDuck, one of more than 20 companies that are making versions of the device, thinks that hoverboards may have larger applications beyond silly pranks. “It could evolve as a new form of transportation for cities and colleges,” Yellin says. And even though British authorities recently caused a stir by outlawing their use on public sidewalks and streets in that country, sales in the U.S. are steadily ticking up. Bear in mind, however, that convenience comes at a cost: prices range from \$350 to \$1,700, depending on the brand and its features.

4.6 MILLION HOVERBOARDS WERE SHIPPED FROM CHINA TO THE
U.S. IN 2015

HOLY COW!

Self-Driving Trucks, Next Big Thing on U.S. Roads



On Interstate 280 outside San Francisco, towering white Volvo semi trucks have been driving themselves around for months under the careful supervision of humans in the cab. Otto, a startup founded by automation experts eager to get their inventions out of the lab and onto the road, has been working to re-invent commercial trucking since the company was founded in early 2016.

Otto, which has already been acquired by Uber, believes there is great incentive for highway-autonomous big rigs to be widely adopted quickly, as they would cut down on fuel and time costs from idling. During a test drive TIME sat in on, the human in the driver's seat twice punched a big red button that disengaged the automated system so he could take over. Still, workers at Otto are hard at work getting rid of the bugs and improving the technology. It may not yet be clear what the future of automated transport will look like, but the industry's innovators want to get there fast.

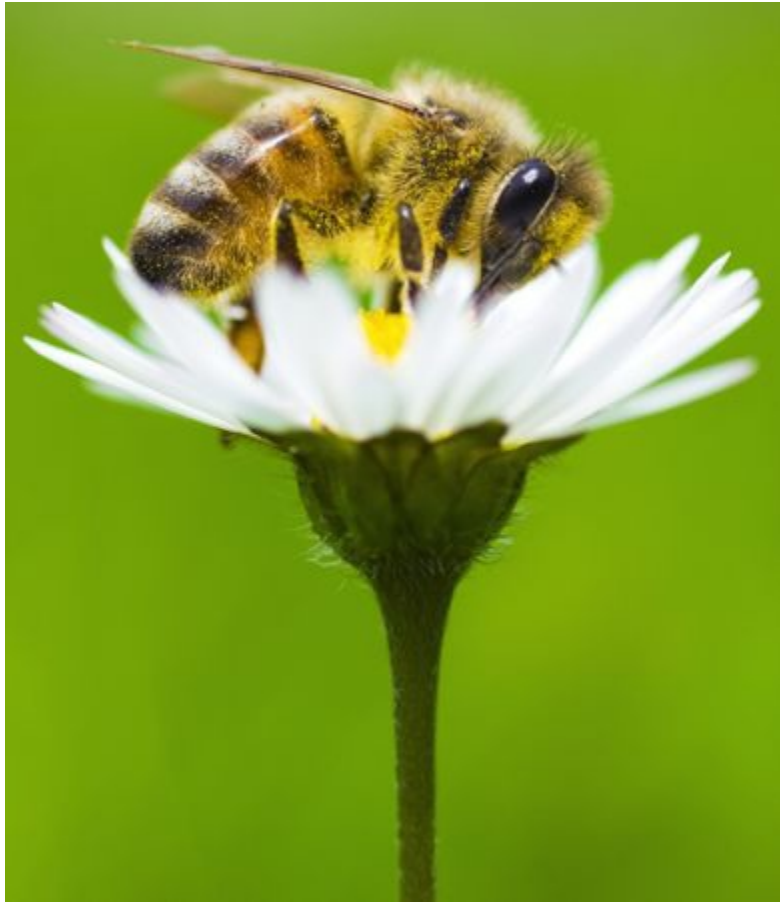
Botany

Bee Trouble ■ Deforestation on the Rise ■ Fertility News ■ Pesticides on Food ■ GMOs and Human Health ■ Endangered Plants ■ An Avocado Shortage ■ Why Flowers Move ■ Food Insecurity in China ■ A Fabled Forest Discovered

The Plight of the Honeybee

Mass deaths in bee colonies may mean disaster for farmers—and your favorite foods

BY BRYAN WALSH



You can thank the *Apis mellifera*, better known as the western honeybee, for 1 in every 3 mouthfuls of food you'll eat today. From the almond orchards of central California—where each spring billions of honeybees from across the U.S. arrive to pollinate a vast crop—to the blueberry bogs of Maine, bees are the unsung, unpaid laborers of the American agricultural system, adding more than \$15 billion in value to farming each year. In June 2016, a Whole Foods store in Rhode Island, as part of a campaign to highlight the importance of honeybees, temporarily removed from its produce section all the food that depends on pollinators. Of 453 items, 237 vanished, including apples, lemons, and zucchini and other squashes. Honeybees “are the glue that holds our agricultural system together,” wrote journalist Hannah Nordhaus in her book *The Beekeeper's Lament*.

And now that glue is failing. Around 2006, commercial beekeepers began noticing something disturbing: their honeybees were disappearing. Beekeepers would open their

hives and find them full of honeycomb, wax, even honey—but devoid of bees. As reports from worried beekeepers rolled in, scientists coined an appropriately apocalyptic term for the mystery malady: colony-collapse disorder, or CCD. Suddenly beekeepers found themselves in the media spotlight, the public captivated by the horror-movie mystery of CCD. Seven years later, honeybees are still dying on a scale rarely seen before, and the reasons remain mysterious. One third of U.S. honeybee colonies died or disappeared during the past winter, a 5.8% increase over the year before and well above the 10% to 15% losses beekeepers used to experience in normal winters.

Though beekeepers can replenish dead hives over time, the high rates of colony loss are putting intense pressure on the industry and on agriculture. Eliminate the honeybee, and agriculture is permanently diminished. “The take-home message is that we are very close to the edge,” says Jeff Pettis, the research leader at the U.S. Department of Agriculture’s Bee Research Laboratory. “It’s a roll of the dice now.”

That’s why scientists are working hard to figure out what’s bugging the bees. Agricultural pesticides were an obvious suspect, specifically a popular new class of chemicals known as neonicotinoids, which seem to affect bees and other insects even at what should be safe doses. Other researchers focused on bee-killing pests like the accurately named *Varroa destructor*, a parasitic mite that has ravaged honeybee colonies since it was accidentally introduced into the U.S. in the 1980s. Others still have looked at bacterial and viral diseases. The lack of a clear culprit only deepened the mystery and the fear, heralding what some greens call a “second silent spring,” a reference to Rachel Carson’s breakthrough 1962 book, which is widely credited with helping launch the modern environmental movement. The loss of the honeybees wouldn’t end the world, but it would leave the planet poorer and hungrier. Yet what’s really scary is the fear that bees may be a sign of what’s to come, a symbol that something is deeply wrong with the world around us. “If we don’t make some changes soon, we’re going to see disaster,” says Tom Theobald, a beekeeper in Colorado. “The bees are just the beginning.”

Ask many beekeepers what’s killing their bees, and chances are you’ll get one answer: neonicotinoids. The chemicals are used on more than 140 different crops as well as in home gardens, resulting in endless chances of exposure for any insect that alights on the treated plants. “The impacts [from the pesticides] are not marginal, and they’re not academic,” says Peter Jenkins, a lawyer for the Center for Food Safety. “They pose real threats to the viability of pollinators.”

Because American farmers have been dousing their fields with pesticides for decades, honeybees—which can fly as far as five miles in search of forage—have been exposed to toxins since well before the dawn of CCD. But neonicotinoids, which were introduced in the mid-1990s and became widespread soon thereafter, are different. The chemicals are known as systematics, which means that seeds are soaked in them before they’re planted. Traces of the chemicals are eventually passed on to every part of the mature plant—including the pollen and nectar a bee might come into contact with—and can remain for much longer than other pesticides do.

Studies have shown that neonicotinoids attack honeybees’ nervous system, interfering

with their flying and navigation abilities without killing them immediately. “The scientific literature is exploding now with work on sublethal impacts on bees,” says James Frazier, an entomologist at Penn State University. The delayed but cumulative effects of repeated exposure might explain why colonies keep dying off year after year despite beekeepers’ best efforts. It’s as if the bees are being poisoned very slowly.

But even if pesticides are a big part of the bee-death mystery, there are other suspects. Beekeepers have always had to protect their charges from dangers such as the American foulbrood—a bacterial disease that kills developing bees—and the small hive beetle, a pest that can infiltrate and contaminate colonies. Bloodiest of all is the multidecade war against the Varroa destructor, which burrows into the brood cells that host baby bees. The mites are equipped with a sharp, two-pronged tongue that can pierce a bee’s exoskeleton and suck its hemolymph—the fluid that serves as blood in bees. And since the Varroa can also spread a number of other diseases—they’re the bee equivalent of a dirty hypodermic needle—an uncontrolled mite infestation can quickly lead to a dying hive.

There’s also the undeniable fact that U.S. beekeepers live in a country that is becoming inhospitable to honeybees. To survive, bees need forage, which means flowers and wild spaces. Our industrialized agricultural system has conspired against that, transforming the countryside into vast stretches of crop monocultures—factory fields of corn or soybeans that are little more than a desert for honeybees starved of pollen and nectar.

The reality is that barring a major change in the way the U.S. grows food, the pressure on honeybees won’t subside. There are more than 1,200 pesticides currently registered for use in the U.S.; nobody pretends that number will be coming down by a lot. Instead, the honeybee and its various pests are more likely to be changed to fit into the existing agricultural system. The agriculture company Monsanto is working on an RNA-interference technology that can kill the Varroa mite by disrupting the way its genes are expressed. The result would be a species-specific self-destruct mechanism—a much better alternative than the toxic and often ineffective miticides beekeepers have been forced to use. Meanwhile, researchers at Washington State University are developing what will probably be the world’s smallest sperm bank—a bee-genome repository that will be used to crossbreed a more resilient honeybee from the 28 recognized subspecies of the insect around the world.

Already, commercial beekeepers have adjusted to the threats facing their charges by spending more to provide supplemental feed to their colonies. Supplemental feed raises costs, and some scientists worry that replacing honey with sugar or corn syrup can leave bees less capable of fighting off infections. But beekeepers living adrift in a nutritional wasteland have little choice. The beekeeping business may well begin to resemble the industrial farming industry it works with: fewer beekeepers running larger operations that produce enough revenue to pay for the equipment and technologies needed to stay ahead of an increasingly hostile environment.

So if the honeybee survives, it likely won’t resemble what we’ve known for centuries. But things could be worse. For all the recent attention on the commercial honeybee, wild

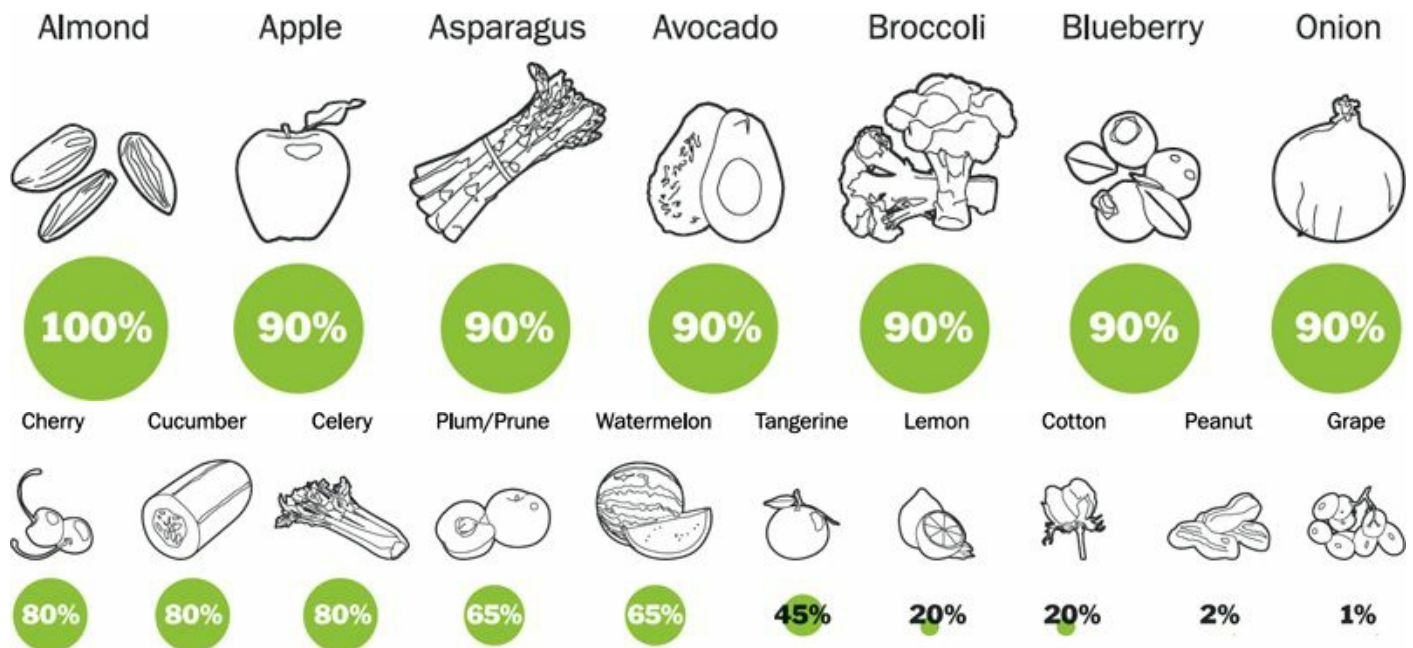
bees are in far worse shape. In June 2013, when a landscaping company sprayed insecticide on trees, 50,000 wild bumblebees in Oregon were killed. It was the largest such mass poisoning on record, and unlike the honeybee, the bumblebee has no human caretakers, no one to tend to its declining numbers. Globally, up to 100,000 animal species die off annually, nearly every one of them without fanfare or notice. This is what happens when one species—that would be us—becomes so widespread and dominant that it crowds out almost everything else. It won't be a second silent spring that dawns; we'll still have the buzz of the feedlot honeybee in our ears. But humans and our handful of preferred species may find that all of our seasons have become lonelier ones.



About 44% of U.S. honeybees died or disappeared in 2015–16, a notable increase in loss even considering the steady drop in bee colonies in the U.S. and Europe for several years in a row

The Impact on the Farm

Although many crops are only partially dependent on bee pollination, others, like almonds, cannot get by without it. According to the USDA, one third of the food in our diet is reliant to some extent on bee pollination.



Here's How Many Trees Humans Cut Down Each Year



Trees play a crucial part in supporting life across the globe, producing oxygen and absorbing climate-change-causing carbon dioxide. But despite trees' importance, humans have had little idea how many of them actually live on planet Earth.

The world is home to more than 3 trillion trees, according to a recent study. (Previous estimates, collected by satellite imaging, suggested that there are just 400 billion trees alive around the world.) Humans cut down 15 billion trees each year, however, and as a result, the global tree count has fallen by 46% since the beginning of civilization.

Trees occupy nearly every corner of the globe, but the study shows that coverage is far from even, and moisture and warmth are some of the factors in how many trees exist in a particular place.

Still, human activity is the greatest predictor of whether trees will survive in a given area. Losses are most dramatic in the tropical regions as land is cleared for agriculture and other commercial purposes. Researchers say the findings may help inform conservation and environmental policy.

A New Study Links Organic Food to Better Fertility



The troubling link between pesticide exposure and fertility isn't new; scientists have already established that people who work with pesticides tend to have lower fertility than those who don't. But for the majority of people who don't work with chemicals, diet is the biggest source of exposure, says Jorge Chavarro, an associate professor of nutrition and epidemiology at Harvard School of Public Health and the senior author of a study published in the journal *Human Reproduction*.

Chavarro and his colleagues wanted to see if pesticide residues left on fruits and vegetables might have a similar effect on sperm, and their findings suggest that they did. Men who ate fruits and vegetables with a lot of pesticides had lower sperm counts and more oddly shaped sperm than those who had lower levels of dietary pesticide exposure.

Men who ate the most high-pesticide fruits and vegetables had a 49% lower total sperm count and 32% fewer sperm that were shaped normally, compared with men who ate the least amount of the high-pesticide produce.

Chavarro says that one study isn't enough to provide definitive proof and that more research is needed to confirm the link. "As far as we are aware, this is the first time that something like this has been reported," he says.

Some Foods Have Many More Pesticides on Them Than Others



Strawberries top the list of produce with the most pesticides, according to a 2016 report from the Environmental Working Group (EWG), followed by apples, nectarines and peaches. Overall, nearly two thirds of conventionally grown produce tested contained pesticides, but the variety and concentration varied greatly between types.

“We see consistent differences between foods,” said EWG senior analyst Sonya Lunder. “This is important for people who want to eat zero pesticides.” A number of factors determine which produce farmers spray with pesticides. Farmers tend to use pesticides for fruit with sensitive skin, like peaches and nectarines. On the other hand, the skin or peel on produce like avocados, pineapples and bananas largely prevents pesticides from affecting consumers who are exposed to them. Avocados, corn and pineapples top the list of produce with the lowest pesticide contamination.

The report looked at a number of factors in U.S. Department of Agriculture data to develop the rankings, including the percentage of a type of produce that tested positive for pesticides, the weight of the pesticides and the average number of pesticides. Consuming produce with multiple pesticides may have negative effects on human health.

“We know everyone needs to eat fruits and vegetables,” Lunder said. “This is an important tool for understanding and making informed choices about the food you purchase.”

GMO Crops May Not Harm Health



Genetically engineered crops pose no additional risks to humans and the environment when compared with conventional crops, according to a 2016 report published by the National Academies of Sciences.

“There have been claims that [genetically engineered] crops have had adverse effects on human health,” the report reads. “Sweeping statements about crops are problematic because issues related to them are multidimensional.”

Still, genetic-modification news is not all good, the report suggests. Widespread use of genetically modified crops, which are often engineered to resist the effects of pesticides, has contributed to worrying levels of pesticide resistance in weeds and insects, while also increasing the use of herbicides and other pest killers on plants. Pests improve in their ability to resist pesticides every time the chemicals are sprayed, creating a vicious cycle of increased spraying and more resistance.

The report comes as public health and environmental advocates continue to push for mandatory labeling of genetically modified food—and it is unlikely to stop those calls for transparency. Until such regulations are instituted, it’s up to consumers to find out which foods are GMO-free.

One in Five of the World's Plant Species Is Now Endangered



The palm oil plant is pushing out other species.

Of the species facing possible extinction, almost 31% are threatened because of expanding demand for agricultural land, including the clearing of many of the world's forests to make way for palm oil production or cattle farming. Demand for timber is jeopardizing 21% of endangered plant species, while construction threatens 13% of at-risk species, a 2016 report found.

Kathy Willis, director of science at the Royal Botanic Gardens, Kew, in England told the *Guardian* she was “reasonably optimistic” that the report could help the world address the threats to plant species. “Plants provide us with everything—food, fuel, medicines, timber—and they are incredibly important for our climate regulation. Without plants we would not be here.”

There's a Serious Avocado Shortage



In July 2016, there were signs of a major domestic avocado shortage, and through the end of the year, there were no signs of it abating. Initially to blame was a record-breaking Southern California heat wave that burned avocado trees and made the fruit unfit for sale. A complicating factor was a price hike on Mexican avocados, many of which are imported to the U.S., where avocados have become increasingly common in the diet. According to the avocado board, a trade group that oversees the industry, the U.S. imported 45 million pounds of Mexican avocados weekly in 2015; in 2016, less than a third of that—about 13 million pounds per week—were making their way stateside. Ongoing strikes in Mexico and California suggest the shortage may, indeed, go on.

Scientists Learn Why Sunflowers Move



Botanists have long wondered just how and why sunflowers turn toward the sun. Now, in a study published in *Science*, a team of researchers report that it's partly in their genes, partly in their hormones and partly in the young sunflower's need to make friends with its favorite pollinator, the bee. So how do the bees figure into it? For them it's mostly about the heat and less about the light. Thermal readings of sunflowers revealed that those that faced the sun in the morning were warmer than those that had been rotated the other way. Bees preferentially landed on those warm sides. When the investigators used space heaters on the cooler sides of the flowers, the bees began to land there too.

All of this is bigger news to botanists than it is to the rest of us. Still, it was millions of years ago that the sun, the flowers and the bees began their cyclic dance. It's nice, at last, to understand why.

China May Not Have Enough Arable Land to Feed Its People



China's food security relies on farmers like Liu Chengbao, an older man who lives in Wang Meng village, where just 300 people remain. But due to a number of factors— young people moving to the cities, arable land being used for development—it's increasingly unsustainable. The nation of 1.3 billion accounts for almost a fifth of the world's population yet has just 7% of its arable land. Moderate to severe soil degradation affects more than 40% of that arable land, exacerbated by overuse of fertilizer, intensive grazing and a reliance on biomass for rural energy.

While China's factories hog the headlines, experts say that agriculture, rather than industry, exerts the biggest toll on the environment, and the long-term implications for the populace can't be understated.

The effect is apt to be a downward spiral, because poverty and land degradation feed into each other. In 2015, China produced 600 million tons of food—the 12th straight annual rise. But over the next several decades, some 300 million Chinese are expected to abandon once-productive fields for jobs in cities. Valuable arable land would then be gnawed away to build urban clusters, where the consumption of meat, grains and dairy products is far higher.

The average Chinese person now eats almost 40 pounds of meat a year, with an additional 66 pounds per person expected by 2030. Already, 70% of China's corn is used to feed livestock rather than humans, as is the case in the West.

Faced with this impending crisis, the Chinese Communist Party has been taking drastic steps to safeguard the nation's food security, including limits on pesticides and the acquisition of foreign land. Time is of the essence for Chinese authorities—and only time will tell if their plan will work.

HOLY COW!

The Fabled Monkey-God Forest May Have Finally Been Located



A stone sculpture found on-site

An ancient lost city from a mysterious culture may have been discovered in the eastern Honduran rain forest. Legend speaks of a “White City” or “City of the Monkey God” so remote that no one has ever found it, reports *National Geographic*.

That is, until a team of American and Honduran archaeologists returned from deep within the Central American nation’s jungle in 2015. The scientists found evidence of settlements and remnants of an unknown civilization that thrived thousands of years ago. Stone sculptures, ceremonial seats, and carved vessels decorated with snakes and other animals made up a cache of 52 artifacts that were visible from ground level. Archaeologists believe much more lies further down.

Archaeology

Human Ancestors ■ Ice Man Fashion ■ Early Meat Eating ■ Mom and Baby Fossils ■ Mummy Birds ■ Ancient Evidence of Death ■ The Oldest Fossils ■ What Killed the Dinos ■ Dinosaur Sounds ■ Really Old Crocodiles

New Human Ancestors Discovered

Controversial findings emerge about a hominid species known as the Hobbits—and about another species never seen before

BY JEFFREY KLUGER



At left, reproductions of “Hobbit” bones found in the Liang Bua cave; at right, real human bones

It was never going to be a fair fight between the humans and the Hobbits—which is a shame, because for a while there, the Hobbits had it pretty good. They lived on the peaceable island of Flores in Indonesia, rich with vegetation, filled with game and safely isolated from other hominin species like *Homo sapiens*. They needed every bit of protection such a sanctuary could offer them: as their unscientific nickname suggests, they were tiny by human standards, just over three feet tall. They had comparatively advanced brains and were capable of making tools, but in a scrap with the bigger *H. sapiens*, they wouldn’t have stood a chance. They survived, we thought, until 11,000 years ago, and whatever wiped them out, at least it wasn’t us.

Except now it looks like, yeah, it probably was. The remains of the Hobbits, properly

known as *Homo floresiensis*, were first discovered in the Liang Bua cave on Flores in 2003, and for more than a decade, few people doubted the prevailing theories about how the species lived and when they died. In 2016, however, a welter of new findings—involving human remains, the disappearance of prey, and new carbon dating of material in the cave—pushed the disappearance of the Hobbits back to about 46,000 years ago. The date precisely corresponds with the time that the expanding *H. sapiens* population would have arrived, powerful circumstantial evidence that the death of the Hobbits should be pinned on humans.

That wasn't all of the big news in the past year about early humans. Paleoanthropologists are still arguing about the 2015 announcement by Lee Berger of South Africa's University of Witwatersrand concerning a cache of 1,550 bones, including 15 complete skeletons, that his team found in a South African cave. Berger pronounced the discovery a new species, dubbed *Homo naledi*, after the name of the cave formation. The species, which lived up to 3 million years ago, had some primitive features—a brain the size of a tangerine, shoulders adapted for climbing—plus one modern, even tender trait: they buried their dead, which is why the remains were found in so well-concealed a place. “*Homo naledi* is a previously unknown species of extinct hominin,” Berger and his colleagues declared in their paper. “[T]his is the largest assemblage of a single species of hominins yet discovered in Africa.”

Not everyone agrees, however. The remains were washed down into the cave by a flood or a landslide, the critics argue, not lovingly placed there by grieving relatives; the bones are much younger than the early analysis suggests, on the order of 50,000 years old; even if the remains are as old as the discoverers say, they are not a new species after all, but kin to one or another well-established line.

It was the kind of unsettling year—with two major findings getting challenged in quick succession—that sparks a lot of fights in labs and faculty lounges. And it was the kind of bracing year too that explains why paleoanthropologists themselves keep coming back for more.

The new thinking about the Hobbits comes from both small and large bits of evidence. The small part involves a pair of teeth also found in the Liang Bua cave. The Hobbits left plenty of their own teeth behind, but the two stray ones, discovered in 2010 and 2011 by a pair of Australian researchers, seemed different—and they were. Examinations revealed that they belonged to *H. sapiens* and carbon dating placed them at 46,000 to 50,000 years old.

That would have put *H. sapiens* in the long-term company of the Hobbits—for tens of thousands of years before the latter's supposed disappearance 11,000 years ago. So how did a fiercely competitive, resource-gobbling species like *H. sapiens* resist the impulse to beat up on the little guy? Apparently, they didn't.

The best prey for any hominin on Flores would have been giant storks, vultures and a species of dwarf elephant known as stegodons. Those animals, however, which were once plentiful, disappeared from the sediment record at about the same 46,000-year-ago juncture at which the teeth were dated, suggesting that when humans came along, they

hunted the island's pantry clean, starved the Hobbits out and moved on.

What's more, the supposed age of the Hobbit bones, 11,000 years, is now thought to be an error. More complete dating of the fossils, soil and sediment in the cave pushed the estimate back to 50,000 years ago, meaning *H. floresiensis* may have vanished long before scientists thought they did. The conclusion: *H. sapiens* arrived in Southeast Asia, outcompeted the native population and then continued their spread around the world, fitting neatly with the new age interpretation. It's possible, says paleoanthropologist Chris Stringer of the Natural History Museum in London, that early *H. sapiens* even bred with *H. floresiensis*, just as they are now thought to have done with Neanderthals.

The catfight over *H. naledi* is more heated, and some of it has less to do with the findings than with the methods. In a field in which analysis of fossils can play out for more than a decade, Berger is accused of rushing—publishing his findings just two years after the discovery was made. Other paleoanthropologists sniff at the journal in which the paper appeared: *eLife*, an open-access publication, as opposed to, say, the venerable *Nature*.

More important is the interpretation of the bones, specifically Berger's argument that they indicate a new species with a sentimental feeling for their dead. William Kimbel, director of the Institute of Human Origins at Arizona State University, believes the ostensible *H. naledi* may be what he calls "a late twig on the branch" of *H. floresiensis*. Fred Grine of the State University of New York, Stony Brook, suggests that the bones could belong to *Homo erectus*.

Further complicating matters, the remains of beetles and snails were found on the fossils, but neither of those animals care for dark, wet surroundings. That indicates that the bones may once have been on the surface, not carefully interred in the cave from the moment or moments of the individuals' deaths. Then, too, there is the fact that while 15 of the skeletons were largely intact, there was a huge scattering of other bones, leading some paleoanthropologists to conclude that, never mind the cave's serving as a respectful burial site, it may have been a place where ritual sacrifices were conducted.

Berger and his collaborators push back, pointing out that some species of snails are often found at burial sites. And while other investigators may dismiss the idea that *H. naledi* buried their dead, the fact is, grieving behavior has been regularly observed in gorillas and chimpanzees, so why is it such a stretch to believe that pre-humans behaved similarly?

Determining the age of the bones would help a lot, but carbon dating is effective to only about 50,000 years and is useless for the million-plus-year time frame in which Berger believes the species lived. Potassium-argon dating can go far deeper in time, but it can be confusing in this case because sediment, rocks and bones of all ages may have been dumped into the cave together.

For now, *Homo naledi* remains one of the great puzzles of paleoanthropology. That's a risk inherent in a field in which the only ones who truly know how pre-human species lived are those pre-humans themselves, and they're not talking. It's up to the modern-day scientists, whom those long-ago ancestors could never have imagined, to tease out the

answers, and to abide the unknown until that work is done.



Lee Berger, a paleoanthropologist, in the Rising Star cave near Johannesburg. The Liang Bua cave excavation site, on the Indonesian island of Flores, is where the fossils of Homo floresiensis were discovered.



For now, *Homo naledi* remains one of the **great puzzles of paleoanthropology**. That's a risk inherent in a field in which the only ones who truly know how pre-humans lived are those pre-humans themselves

Scientists Solve the Mystery of 5,300-Year-Old Ice Man's Clothes



About 5,300 years ago, a man now known as Ötzi had a bad day. Nobody knows how things unfolded, but he ended up dead, with an arrow wound, in a glacier in the Ötztal region of the Alps. There he lay until two hikers found him in ice melt in 1991. In the years after, investigators studied his body and his belongings extensively, but figuring out the makeup of his clothing—specifically, which animals died to keep him warm—was impossible. The tanning process destroys DNA, ruling out ordinary genetic sequencing.

In a study published in *Nature*, however, investigators revealed that they had found a way, sequencing not the genes in the nucleus of the cell, but in the mitochondria—the cell's energy-generating organelle—which survives tanning. Ötzi, that method revealed, relied on a lot of different critters to keep himself clothed. His leggings were goat, his shoelaces came from cattle, his loincloth was sheep, and his coat was made from both sheep and goat. The hat, however, was the garment Ötzi likely had to work hardest for: it came from a brown bear. They may have died young in the Copper Age, but they lived large.

Humans Used Tools to Eat Meat 250,000 Years Ago



If you're a developing species with dreams of dominating your home planet, you need to learn to use tools—first to kill and prepare prey and then, once you've got your food needs worked out, to build things. Exactly when we picked up our first tool is unclear, but a study in the *Journal of Archaeological Science* found firm evidence that hominins used tools to butcher animals as long as 250,000 years ago, or at least 50,000 years before the earliest modern humans appeared in Africa.

Researchers studied 44 well-preserved stone tools found in a dried oasis in Jordan and subjected them to antiserum testing looking for proteins, specifically proteins from food animals. The surfaces of the tools would have long since been worn clean, but the microscopic cracks on and around the blades might still hold evidence. And on 17 of the tools, they did. The investigators found protein markers indicating the blood of rhinoceros, duck, horse, camel and wild cattle. All of them would have been indigenous to the region where they were found.

The early hunting and butchering had cascading effects for later human species, providing the protein needed to nourish the body's most calorie-intensive organ: the brain. Meat may not be something modern humans need as much—or even at all—as more and more diets allow us to get our protein from other sources. But it was an absolute necessity long ago. With the smarts to make the right tools and eat the right diet, we were able to get smarter and smarter still.

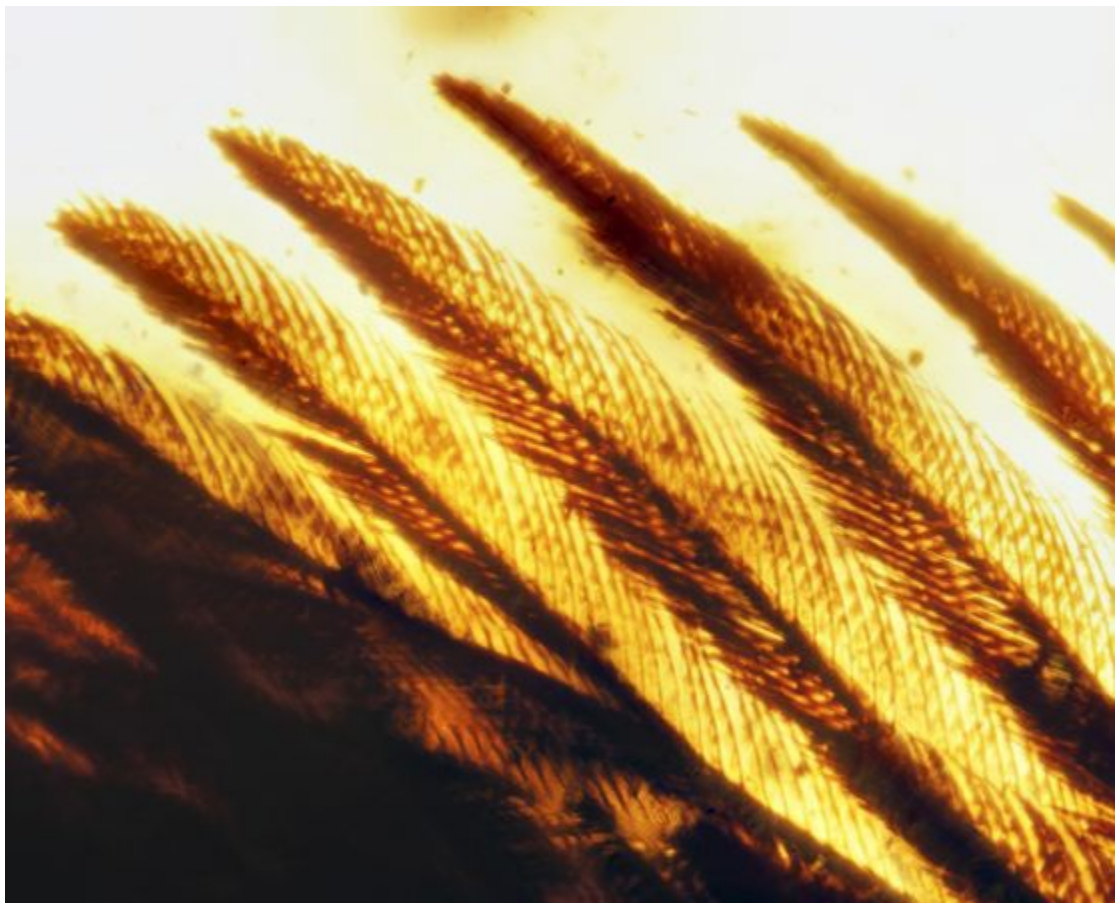
A 4,800-Year-Old Fossil Shows Motherly Love



Archaeologists in Taiwan spent a year excavating four dozen graves that were nearly 5,000 years old and in one of them found a poignant tableau: a mother cradling a baby. The site has archaeological significance because it is thought to mark the earliest evidence of human activity on the island, but nobody was prepared for what the shared grave held.

“When it was unearthed, all of the archaeologists and staff members were shocked,” said Chu Whei-lee, a curator at Taiwan’s National Museum of Natural Science. It’s impossible to know how the pair died, but they were laid to rest in a way both surely would have approved. “The mother was looking down at the baby in her hands,” said Chu.

Mummified Wings Show How Little Birds Have Changed



When something works, it doesn't pay to mess with it. That seems truer than ever with the discovery of bird wings mummified in amber from the age of dinosaurs, showing that their architecture has not changed substantially for up to 100 million years.

The study, published in *Nature Communications*, evaluated what are believed to be the wings of bird-dinosaurs called enantiornithes. Previous research has shown that many dinosaurs may have had feathers, but the study provides new details not available on bones, feather and tissue that have been fossilized in the earth.

The amber artifacts, found in Burma, contain very small, detailed wings with the fine digits still intact. "We usually get small fragments or isolated feathers," says study co-author Ryan McKellar. "We don't get something like this. It's mind-blowingly cool."

How One of the World's Oldest Human Ancestors Died



A model of Lucy, the oldest known human ancestor

The world's most remarkable human ancestor, widely known as Lucy, probably died in a unremarkable way: she fell from a tree, according to new research.

Scientists behind the study, published in the journal *Nature*, already knew that some of the fossil's bones showed fractures, but they wanted to look closer, taking CT scans of the 3.18-million-year-old remains to evaluate what caused Lucy's injuries. A comparison of the broken bones with those in clinical cases of chimpanzees led to the new conclusion.

A series of clean breaks in the right upper arm were the most telling indication of the kind of accident that took Lucy's life. She likely outstretched her arms to break her fall, causing compression fractures, according to the study. She sustained other fractures on her left shoulder, left knee, left pelvis and one rib.

"Death is one of those things that really does permit us to bridge fairly deep breadths of distance between us and others," said study author John Kappelman, a University of Texas at Austin paleoanthropologist, in a video.

Lucy and her fellow Australopithecine are thought to have been principally ground dwellers. But she may have climbed into the trees one night to find safety from predators.

The Oldest Fossils Ever Were Found in Greenland



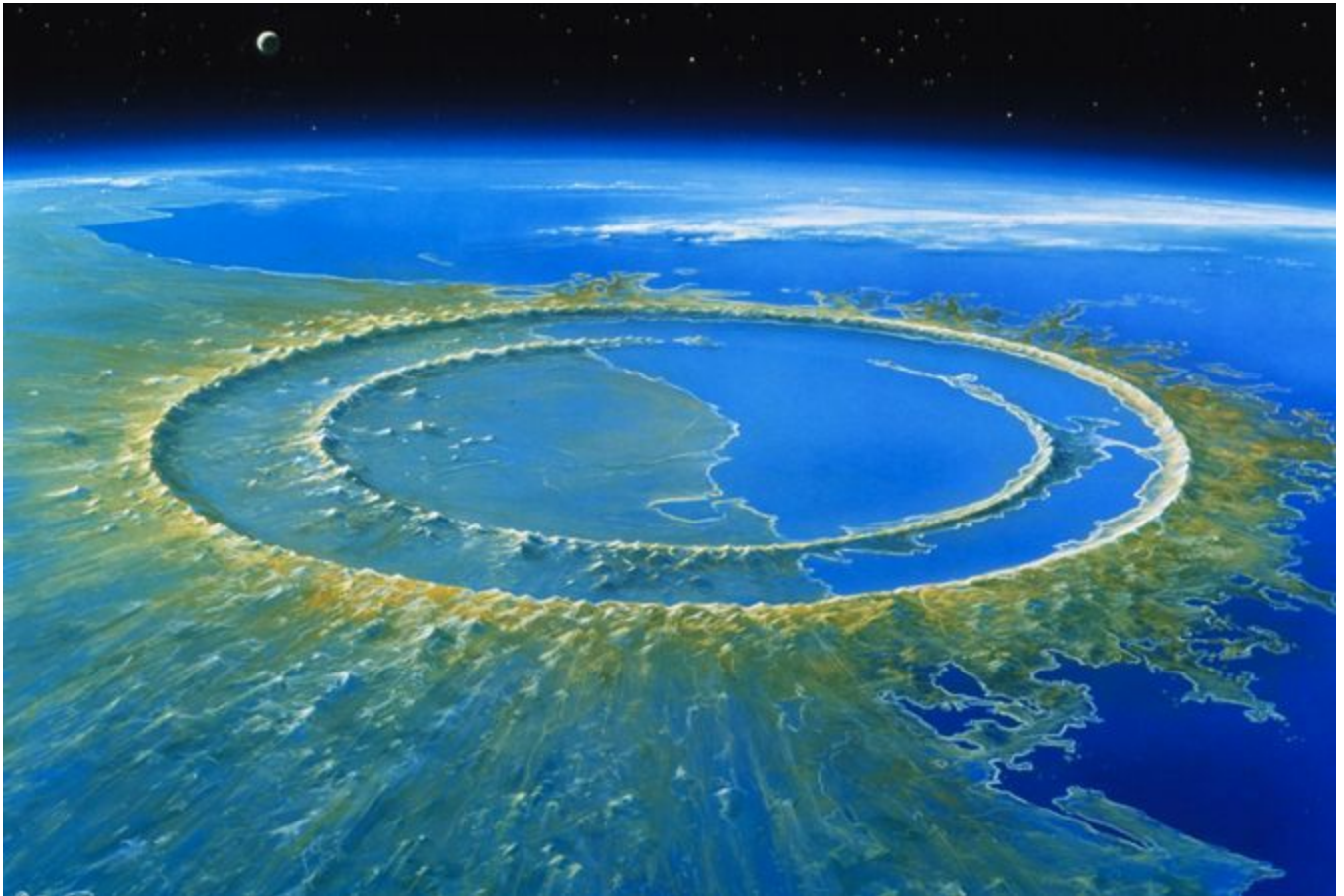
A field team explores Greenland.

Scientists have found the oldest physical evidence of life on Earth in fossils trapped in 3.7-billion-year-old Greenland rocks—220 million years older than any previously unearthed fossil evidence, researchers reported in *Nature*. The fossils in the rocks aren't much, merely stromatolites—layered calcium formations secreted by microbial communities. But they're a sign of life all the same and have implications that go beyond our own planet.

“If we have life at 3,700 million years on Earth, did it exist on other planets? Because Mars 3,700 million years ago was wet,” said Clark Friend, a researcher in the study.

The fossils reach back to Earth's Archean eon, which lasted from about 4 billion to 2.5 billion years ago. Finding biological artifacts in Archean rocks is rare because they tend to be heavily twisted and altered, but the researchers had a stroke of luck when they found an outcrop of rocks under a melted patch of snow in Greenland that had remained comparatively pristine. Wavy lines in the rock revealed evidence of stromatolites—a signal from one of Earth's simplest residents to its most complex one, billions of years later.

How Fossil Fuels May Have Killed Off the Dinosaurs



Artwork of the Chicxulub impact crater on the Yucatán Peninsula, Mexico

Think the modern world has a problem with what fossil fuels are doing to the atmosphere? Turns out the fossils themselves—the dinosaurs—had it even worse. According to a paper published in *Nature*, it was a problem so severe it cost them their lives.

Many people know that an asteroid strike was the proximate cause of the dinosaurs' extinction, producing a debris cloud that led to the Earth's cooling. The rock was a big one—a six-mile-wide projectile that struck the coastline of the Yucatán Peninsula. The massive hit threw up a sulfuric cloud that swirled through the atmosphere, causing the cooling of the planet and leading to the death of nearly 90% of the world's land-dwelling creatures and 10% of the shallow-sea-dwelling ones.

So case closed, right? Not quite. The asteroid had a co-conspirator in the form of massive volcanic eruptions in a central Indian region known as the Deccan Traps. They contributed to the atmospheric shrouding and global cooling. Now, it seems, there was another player still: soot.

Studying the geological stratum corresponding to the asteroid strike, investigators from Tohoku University in Japan looked for traces of coronene, benzopyrene and benzopyrylene—byproducts of burning oil, which was ignited by fires the asteroid triggered. But what could have been the source of the oil?

The dinosaurs that were alive at the time of the extinction had certainly not made the jump from animal to organic waste to fossil fuel yet, but the ones that died during the Jurassic period—up to 201 million years ago—and earlier could have. The haze produced by the burning would have lingered in the atmosphere far longer than other aerosols produced by the blast, leaving a sustained chill that the dinosaurs could not survive.

The irony, of course, is that the die-off left room for mammals to emerge and expand. Some of those species became mildly intelligent—and one became exceedingly so, enough that it eventually learned to invent the internal combustion engine and pump and burn oil on its own. That, the dinosaurs could tell you, is a tricky game to play.

**66 MILLION YEARS AGO, A SIX-MILE-WIDE ASTEROID STRUCK,
LEADING TO THE DEATH OF NEARLY 90% OF THE WORLD'S LAND-
DWELLING LIFE-FORMS**

Dinosaurs May Have Cooed Instead of Roared



Not only did some dinosaurs have feathers, but according to new research, they may have dispensed with terrifying roars in favor of coos or mumbles. After a comprehensive review of vocal data from bird and crocodile species, scientists from universities in Arizona, Texas, Utah and Canada found that dinosaur sounds may be what they call a “closed-mouth vocalization.” According to the research, published in *Evolution*, a similar example would be the coos of a dove, in which sounds are emitted through the skin and neck area while the beak is kept closed.

“Our results show that closed-mouth vocalization has evolved at least 16 times in archosaurs, a group that includes birds, dinosaurs and crocodiles,” said study co-author Chad Eliason of the University of Texas’s Jackson School of Geosciences in a statement.

HOLY COW!

The Secrets of the 13-Million-Year-Old Crocodile



If you must swim with crocodiles, the time to do it was 13 million years ago, and the place was Peru. That's because although the jaws of an extinct Amazon species were very well-developed, its eyes were only partway along, giving you a chance of surviving your swim. That has broader evolutionary lessons.

One of the key features of the crocodile's face is protruding eyes, allowing it to cruise along just beneath the surface while it hunts. But a study published in *PLOS One* found that while Peruvian crocodiles of that era had generally modern faces, the eyes lagged behind. On the other side of the world, Indian crocodiles had gotten that memo and developed their eyes. That's an example of what's known as parallel evolution, with separate populations facing the same pressures coming up with the same solution. It doesn't, however, mean they do it on the same timeline. The winner, in this round, is the Indian croc.

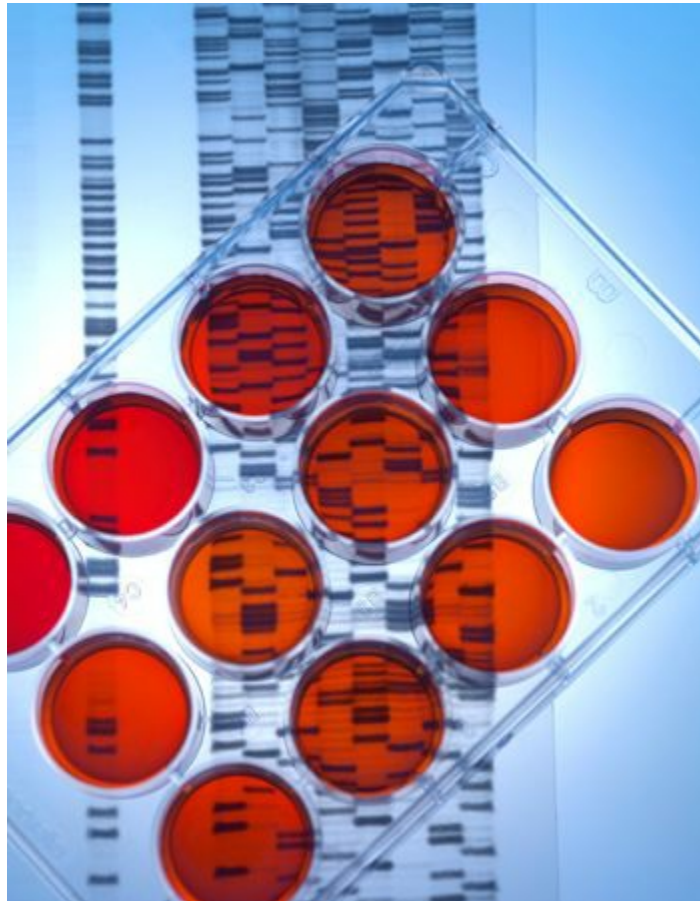
Genetics

Prenatal Testing ■ Mosquito Bites ■ Coffee Addiction ■ Dad's DNA ■ The Science of Procrastination ■ The Genetics of Aging ■ The Secret of Aging ■ On Being a Lefty ■ A Gene for Fat Loss?

The New Science of Predicting Your Child

Prenatal genetic screening has changed what—and when—parents learn about their offspring

BY EMILY OSTER



I have two children. At the moment, all I know about their genes is that they both have 46 chromosomes, and one is XY and one is XX.

I try to treat them equally, to assume equal potential. But what if I knew my daughter carried a “smart” gene and my son did not? When he came home from school with a B, would I assume it was because of his genes and not push him to try harder? And what if I could have known this before he was born, at a time when he was just a little blip on an ultrasound? Frankly, I’m not sure I would trust myself with that information.

Such knowledge, of course, isn’t possible yet. For one thing, we haven’t found many genes that can reliably predict intelligence. And at the moment, even if we did know what genes we were looking for, we wouldn’t be able to find them very early in

pregnancy. But thanks to a new kind of prenatal genetic testing, this may soon change.

While prenatal genetic testing has been around since the 1960s, including amniocentesis, which allows doctors to identify genetic disorders in utero, the recent introduction of “cell-free fetal DNA testing” has altered the landscape of early genetic sleuthing even further. It is sold under the brand names Harmony or MaterniT21, among others, but has technology that is broadly consistent, relying on a sample of maternal blood and showing accuracy rates approaching those of a fetal diagnostic test like amniocentesis or chorionic villus sampling (CVS), but without any risk to the fetus. In other words, these new tests provide the best of both worlds—and a recipe for moral fission.

This represents a significant technological breakthrough. Because amniocentesis and CVS analyze a baby’s DNA just one step removed, via amniotic fluid or placental material, they’re invasive, requiring the insertion of a needle into the womb and the removal of some cells, which comes with certain risks.

As the name implies, cell-free fetal DNA is fetal DNA that exists outside of cells, so it can be obtained from the mother’s plasma. Studies have shown 10% to 20% of DNA from a mom’s circulating plasma is fetal in origin, which means that researchers can be confident that a large share of what they are extracting comes from the fetus. In principle, if one could simply separate the maternal and fetal DNA, it would be possible to sequence the full fetal DNA using this procedure.

Technology is not quite there yet, so this procedure currently works by looking for things in the cell-free DNA that wouldn’t be there if the DNA were only the mother’s.

Think about it in terms of gender: women have two X chromosomes; men have one X and one Y. Imagine you look in a mom’s cell-free DNA and find a bunch of Y chromosomes. The baby will be a boy, right? If you don’t see any Y chromosomes, a girl.

Similarly, a fetus with Down syndrome has three copies of chromosome 21, rather than two, but two copies of all the other chromosomes. So if you look at a mix of fetal and maternal DNA together from a genetically normal mother and see relatively more copies of chromosome 21, you would suspect the baby has Down syndrome. If any chromosomal imbalance is striking enough, the test results will flag a potential problem.

At the moment, these tests fall short of what is possible with amniocentesis or CVS testing. One reason is that they focus on only the three most common trisomies: Down syndrome (trisomy 21), trisomy 18 and trisomy 13. Invasive testing will detect other trisomies, and can detect other types of chromosomal problems. Another shortcoming: both false negatives and false positives are possible.

This procedure relies on a statistical threshold test: sufficiently imbalanced and the test pings “positive.” Not sufficiently imbalanced and it comes up negative. However, sometimes the imbalance in the chromosome counts isn’t striking enough to flag as a positive test, even when the fetus does have a chromosomal abnormality. This is what is called a false negative. And on the other side, sometimes the chromosomes look imbalanced in the sample, but the baby is fine. This is a false positive.

False negatives are pretty rare in these new blood tests—for a woman in her early 30s with a negative result on this screening, the chance of a baby with a chromosomal abnormality is about 1 in 90,000. False positives on this test are also limited, but they matter more. For that same woman in her early 30s with a positive test result, the chance of having a baby with a chromosomal problem is about 66%. In other words, 1 out of 3 women who receive results indicating abnormalities would go on to have a baby who is genetically normal.

Experts agree that consequential decisions about a pregnancy should not be made without an invasive test as a follow-up. But this is likely to be a temporary issue. Effectively, the problem is one of genetic sequencing capacity and statistics. Already these tests are close to perfect on detection of gender. And the precision with which genetic predictions can be made will also improve. It is likely we are more than a few years away from the ability to use these tests as diagnostics.

As these tests improve, so too will the range of conditions they can detect. Researchers have reported on a case in which they used a version of this test to detect a small genetic issue called a microdeletion. The impact of this microdeletion, which was passed on from the mother, is an increased risk for nearsightedness and mild hearing loss. The mother in the study learned that she was passing on her poor eyesight and bad hearing to her child.

In principle, this technology could be used to detect anything for which we have a known genetic link. Researchers engaged in genome-wide association studies have, in the past few years, made progress on identifying a few genes that code for intelligence. Imagine you've tested yourself and you know you carry one of these intelligence genes but, sadly, your spouse does not. Now imagine you can easily learn if your fetus got your smart genes, or your spouse's not-so-smart ones. Or your genes for height, your risk for obesity and your spouse's gene for stubbornness (OK, we haven't found this one yet).

Now take it a step further. Fetal DNA begins to circulate in the mother's blood at the very start of pregnancy. At the moment, these tests wait until 10 or 11 weeks of pregnancy so that the concentration of fetal DNA is high enough to use for accurate detection. But as the sequencing and statistics improve, we may find that it is possible to do the same testing at eight weeks. Or six.

What if you could know, at six weeks of pregnancy, whether your child would inherit your height or hair color or athletic prowess? As I mentioned previously, early gender testing is already used for gender-selective abortion, largely outside the U.S. This was true even when gender detection was not possible until 18 or 20 weeks.

These technologies will raise questions far beyond gender. Many people terminate a pregnancy when they learn the fetus has Down syndrome. What about learning that the child will have autism? We are holding Pandora's box. Once we open it and let the information out, we lose control over what it is used for.

I would argue there are further implications. Let's say I find out my fetus has an increased genetic risk for obesity, and I ultimately have that child. How will I treat her? Will I obsess about everything she eats, every ounce of baby fat that doesn't immediately

melt away? Will she grow up to be obese, or have an eating disorder I was party to with my worry? Could this actually make things worse rather than better? The idea that more information is better relies on our ability to ignore it.

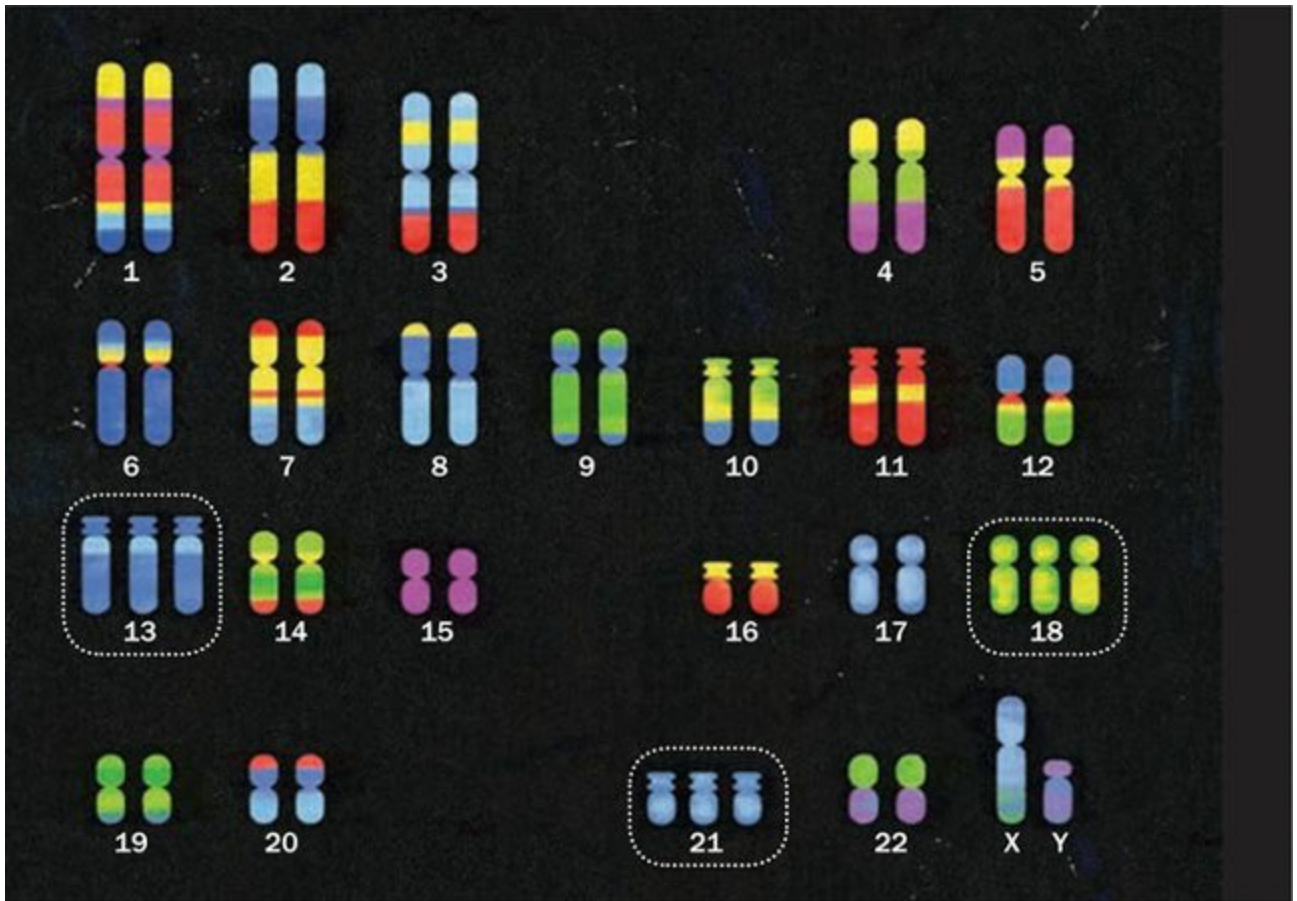
I'm trained as an economist, and one of our general principles is that more information is better. Information helps us make better—more optimal—decisions. And, crucially, more information cannot make you worse off, since you can always just ignore it. Under this theory, these advances in genetic testing should be welcomed without reservation.

In many dimensions, the improvements in testing bring only good. The ability to more accurately detect serious genetic conditions earlier in pregnancy allows women and their partners to make difficult decisions about pregnancy termination earlier in the pregnancy when the medical complications are less significant.

The balance between the value of information and the possibility of misuse is a difficult one. It would be a shame to fail to pursue technologies that are likely to deliver great gains. At the same time, it is naive to pursue them without thinking about their consequences. And we should start thinking about these now.

Ready or not, the future is coming.

Oster is a professor of economics at Brown University and the author of Expecting Better.



Some of the most commonly detected genetic abnormalities occur at chromosomes 13, 18 and 21—which manifest as Patau, Edwards and Down syndromes, respectively

Four methods for prenatal genetic testing



Method: ULTRASOUND

Common since: 1960s

What it does and how it works: Allows doctors to identify physical signs of genetic problems. A probe transmits high-pitched sound waves into the belly. Visible fluid buildup on the back of a fetus's neck may be an early sign of a disorder

Performed at: 11 to 14 weeks

Risks: Noninvasive. Effects of repeated ultrasounds on the fetus are unknown

Accuracy of genetic results: Abnormal results must be confirmed with a diagnostic test



Method: **AMNIOCENTESIS**

Common since: 1960s

What it does and how it works: Identifies chromosomal abnormalities, inherited diseases and defects in the spinal column or brain. A needle through the belly extracts amniotic fluid, which contains fetal cells that are then analyzed

Performed at: 15 to 20 weeks

Risks: Miscarriage occurs about 1 out of every 1,000 procedures

Accuracy of genetic results: 99%



Method: **CHORIONIC VILLUS SAMPLING (CVS)**

Common since: 1980s

What it does and how it works: Identifies chromosomal abnormalities and inherited diseases. A needle through the belly or a catheter through the cervix suctions cells from the placenta. Placental tissue contains the same genetic material as the fetus

Performed at: 10 to 13 weeks

Risks: Miscarriage occurs about 1 out of every 500 procedures

Accuracy of genetic results: 98% to 99%



Method: **MATERNAL BLOOD TEST**

Common since: 2011

What it does and how it works: Allows doctors to assess the risk of chromosomal abnormalities. A blood sample is taken from the mother. Maternal blood contains fetal DNA, which passes through the placenta

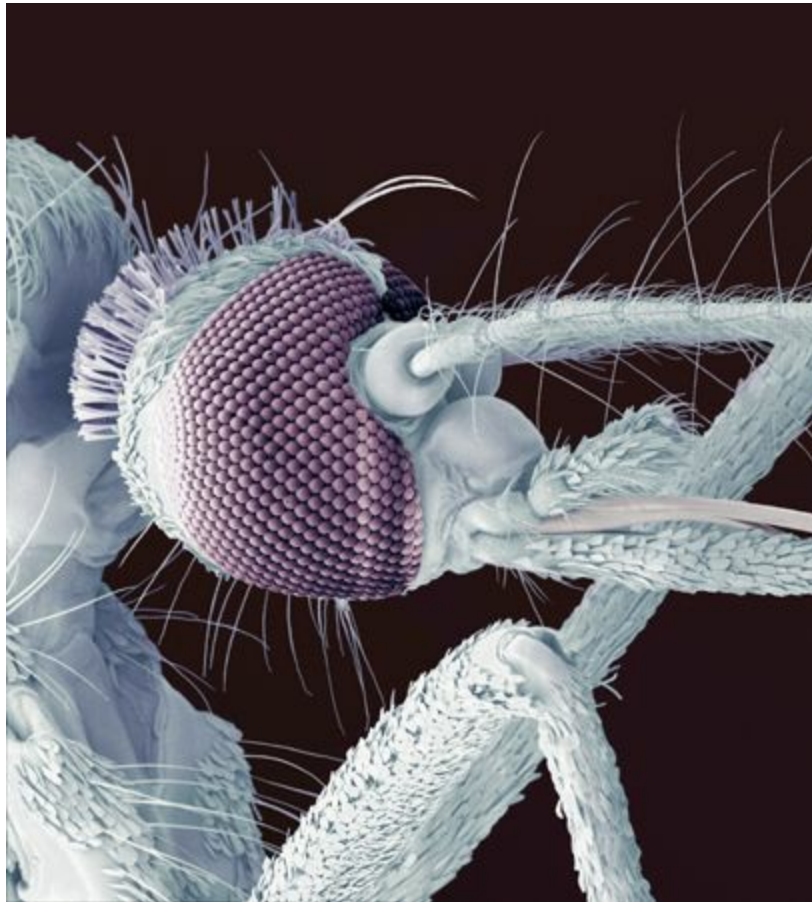
Performed at: 10 weeks or later

Risks: Noninvasive

Accuracy of genetic results: Detects 99% of Down-syndrome cases; up to 50% of positive tests are false positives

SOURCES: ACOG; AMERICAN PREGNANCY ASSOCIATION; CDC; HUMAN REPRODUCTION UPDATE; JOHNS HOPKINS UNIVERSITY; MAYO CLINIC; NEW ENGLAND JOURNAL OF MEDICINE; NIH; NSGC

Scientists Discover Why Some People Get So Many Mosquito Bites



If you're always getting mosquito bites, it might be because of your genes. In a study published in the journal *PLOS One*, researchers worked with identical and non-identical twins to ferret out what role genes might play in how attractive we are to insects. They paired twins, some of the sets identical, some not, and placed one member of each set at one end of a Y-shaped tube, then released mosquitoes into the third end, allowing the mosquitos to choose which twin to attack. Identical twins were more similar in their level of attractiveness to the mosquitoes—in this case, by their odor—than non-identical twins, which suggests that genes may indeed play a role.

Though the sample size was small, the findings may be helpful for preventing mosquito bites. If scientists can pin down the genes responsible repelling mosquitoes, for example, that might lead to novel ways of protecting against bites and preventing the spread of diseases such as Zika and malaria. “In the future we may even be able to take a pill which will enhance the production of natural repellents by the body and ultimately replace skin lotions,” said study author James Logan, a senior lecturer at the London School of Hygiene and Tropical Medicine.

Your Coffee Addiction May Be in Your DNA



Some people can't start the day without a piping hot cup of coffee (or two or three), and the reason may be in their genes. By comparing coffee-drinking habits and the genes of populations of people living in Italy, researchers identified a gene called PDSS2 that could play a role in caffeine metabolism. In their study, published in *Scientific Reports*, the scientists found that people with greater expression of the PDSS2 gene also reported drinking less coffee. They believe the gene regulates how caffeine is metabolized in the body. "The hypothesis is that people with higher levels of this gene are metabolizing caffeine slower, and that's why they're drinking less coffee," says study author Nicola Pirastu, then at the University of Trieste in Italy. "They need to drink it less often to still have the positive effects of caffeine, like being awake and feeling less tired."

The study isn't the first to link genetics to a propensity to drink more or less coffee. An October 2014 report described six genetic markers that were associated with a person's responsiveness to caffeine. Understanding how genes influence caffeine intake is important, researchers say, since coffee has been linked to a variety of health benefits like healthier arteries, a lower risk of Type 2 diabetes and potentially even a longer life, as well as influencing the breakdown of some medications.

Humans Are More Genetically Similar to Their Dads



Every parent wants their child to be just like them, but new research shows that dads may have an advantage, at least from a genetic standpoint.

According to a study by the University of North Carolina's School of Medicine published in *Nature Genetics*, mammals use more DNA from the father than the mother when generating mutations—the genetic process that makes us who we are. Every time a cell divides and copies its DNA, changes and mistakes are made. Most of these don't have much of an impact, but some do.

The scientists, led by genetics professor and senior author Fernando Pardo-Manuel de Villena, focused their attention on these mutations that actually changed gene expression. They found that of the 80% that did, several hundred genes tended to come from the dad.

The authors believe a similar bias would exist for human subjects. Pardo-Manuel de Villena called the results “an exceptional new research finding that opens the door to an entirely new area of exploration in human genetics.”

New Early Testing Is Saving the Lives of Newborns



In every Neonatal Intensive Care Unit (NICU), about a third of babies are there because doctors simply don't know what's wrong with them. They may have seizures or may not be eating or breathing properly, and nobody knows why. But advances in both the depth and speed at which researchers can sequence genomes may finally provide some answers. In a paper published in *Genome Medicine*, scientists at Children's Mercy Hospital in Kansas City have cut the time it takes to draw blood from a newborn and produce a genetic diagnosis from 50 to 26 hours.

"Fully 60% of babies being tested are getting a diagnosis," says Stephen Kingsmore, the senior author of the paper, now at Rady Children's Hospital in San Diego. And that can save their lives. For some, the testing discovers a nutrient that the baby can't break down because of certain genetic mutations, so changing the newborn's diet can reverse the symptoms and stop further damage to the baby's health. The sooner such diagnoses can be made, says Kingsmore, the less potential long-term harm the infant suffers.

So far, the group has only tested the rapid version of the test after the fact, on babies who had the longer 50-hour test. And the results are encouraging; the rapid test was 99% accurate in finding and detailing the same mutations. Before such screening can become more widespread, it needs to be tested in a real-world NICU setting, and its cost must come down from its current \$20,000 range. Finding more ways to automate the analysis of the genetic variants and identifying the DNA differences of interest will do that, says

Kingsmore. It will also make the test more accessible to more pediatric centers that may not have genetic medicine experts on hand. “We want to empower NICUs all around the country so babies . . . can see the benefits of this,” he says.

**A DATABASE CALLED THE PHENOMIZER CONTAINS 6,000 GENETIC
VARIANTS KNOWN TO CAUSE PROBLEMS IN NEWBORNS**

There's New Insight into Why We Procrastinate



At some point, we've all put off today what can be done tomorrow. But how much you tend to procrastinate may have a lot to do with your genes, a study published in the journal *Psychological Science* suggests.

Researchers at the University of Colorado looked into the possible genetic roots of this habit by surveying 181 identical-twin pairs and 166 fraternal-twin pairs. The twins were evaluated on their ability to set and maintain goals, their propensity to procrastinate and their impulsivity.

Prior research has indicated that procrastination and impulsivity are genetically linked. Being impulsive has an evolutionary advantage, the researchers point out, because it would have helped our ancestors with everyday survival. Procrastination, on the other hand, may be more of a modern phenomenon, since we now focus on long-term goals, from which we can easily get distracted.

Based on the behavioral similarities in twins, the researchers concluded that procrastination can indeed be genetic, and that it seems to have some genetic overlap with impulsivity. The researchers also suggest that procrastination is an evolutionary byproduct of making the rash decisions that go along with being impulsive.

"Learning more about the underpinnings of procrastination may help develop interventions to prevent it, and help us overcome our ingrained tendencies to get distracted and lose track of work," study author Daniel Gustavson said in a statement.

Now the only thing chronic procrastinators might care about is, will there ever be a cure?

Some Genes Actually Affect How You'll Age



To figure out which genes help us to live longer without getting sick, researchers from the Scripps Translational Science Institute focused on those rare elderly people who have genetic changes responsible for diseases linked to aging, such as heart problems, cancer, dementia and diabetes, but somehow don't get sick. They sequenced the genomes of these so-called "wellderly" and compared their results with those from similarly aged people who did have the chronic diseases associated with aging.

What set the wellderly apart was a set of genes that related to their cognitive function. They were less likely to have the deleterious form of the ApoE gene that is linked to a higher risk of Alzheimer's disease.

But that doesn't mean genes are the only way to age gracefully. It's likely that for healthy aging, it's necessary to both have genes that lower the risk of chronic diseases (such as avoiding the harmful form of ApoE), as well as having genes that confer some type of protection against the damaging effects of chronic illnesses. The latter haven't been identified yet, but scientists are working on figuring out what they are, thanks to clues provided by people like the wellderly.

A Genetic Explanation for How Old You Look



Call it “not aging well,” or looking older than your years, but the unfortunate reality is that some people simply look older than they actually are. And in a study reported in *Current Biology*, scientists say that a person’s youthful or aged appearance can be partly traced to different versions of a specific gene.

Called MC1R, this particular gene is responsible for inflammation in the body and for repairing damaged DNA. After scanning the entire genome, the scientists found that this one gene stood out for having different forms in people who looked older than they actually were versus people who looked younger than their age (as assessed by people in the study who looked at their photographs). People who had certain forms of the MC1R gene looked about two years older than they were, while people with other variants looked younger.

It’s not clear yet exactly how age-appearance genes work. While MC1R is critical for melanin, or skin pigment, it likely contributes to aging in a different way. That’s because the effect remained the same for both darker- and lighter-skinned people and for people who spent a lot of time in the sun and those who didn’t. Since MC1R is also involved in DNA damage and repair processes and inflammation, the researchers believe that some versions of the gene may impede DNA repair, contributing to quicker aging of cells.

It’s also unlikely that MC1R is the only gene that contributes to how old we look. Scanning more people will reveal more variants in different genes that play a role in aging and the appearance of aging. “This is just the first gene,” says Manfred Kayser, a professor of forensic molecular biology at Erasmus University in the Netherlands and

one of the co-authors of the study. “We hope that once . . . we find more genes, they will lead us more directly toward pathways that help us understand how old we look on the outside and how that differs from how old we are on the inside.”

The Scientific Basis for Being a Lefty



There was once a time (a long, long time ago) when people believed that being left-handed meant a person was more prone to “dealings with the devil” and that the trait should be corrected through various brutal trainings. Thankfully, the prejudice is gone, but people are still curious—why do some kids grow up left-handed versus right-handed?

Numbers suggest that about 90% of people are right-handed and 10% use their left hand predominantly. Some researchers believe that being left-handed is at least partially related to genetics, though whatever role genes play isn’t likely to be a simple one. Some experts point out, for example, that if there were just a dominant gene or genes regulating handedness, then left-handedness would have evolved out of existence by now in favor of right-handedness.

More likely is that a bunch of genetic factors, not to mention environmental ones, are involved. One study, published in *PLOS Genetics*, identified genes that can influence the symmetry in the brain. It’s possible that some of these genes are related to handedness.

Other experts say genetics may be responsible only 25% of the time and that handedness may be pretty random and more dependent on cultural factors rather than inherited ones.

While experts are still sorting out the reasons, scientists have shown that there don’t appear to be any differences between right- and left-handed people when it comes to personality traits like extraversion, agreeableness, conscientiousness, emotionality and openness to experience.

HOLY COW!

A Fat-Burning Gene May Help Weight Loss



Not all fat is created equal, and one type in particular, brown fat, seems to be the Holy Grail—it can turn more quickly into energy for cells and therefore melt away without building up in those unwanted bulges

Now scientists report in the *New England Journal of Medicine* that they have connected the dots between the strongest gene associated with obesity, FTO, and a way to make white fat act more like brown fat. Certain mutations in FTO can give white fat fewer couch potato tendencies and help us derive energy from it more easily.

The next step will be to manipulate these genes and this pathway in human patients—likely those who carry the mutations that predispose them to obesity—to see if the intervention has an effect on their weight and fat composition. If those studies confirm the role that these genetic mutations play, burning fat more efficiently may be a matter of duping the DNA.

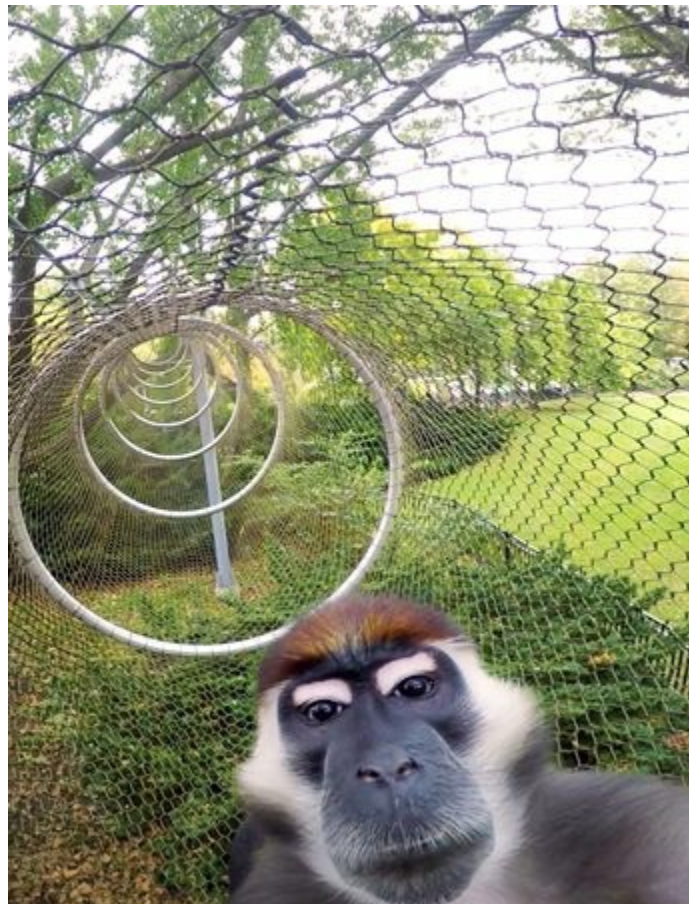
Zoology

Future of Zoos ■ Why Cats Don't Need Humans ■ Whale Talk ■ What Elephant Cancer Says About Humans ■ Why Tigers Are Rebounding ■ The Importance of Biodiversity ■ What Dogs Hear ■ Why Elephants Still Face Threats ■ Bird Love

The Truth About Zoos

New discoveries about the nature of animals, plus pressure from animal-rights activists, have forced zoo leaders to rethink their facilities

BY JUSTIN WORLAND



A colobus monkey explores an enclosed path at the Philadelphia Zoo.

For a mother escorting her kids through the Philadelphia Zoo on a recent Friday afternoon, it was a close encounter of the ferocious kind. Directly in front of them as they strolled down the zoo's main walkway was a Siberian tiger, a 400-plus-pound carnivore capable of chasing down and tearing apart an antelope in moments. But rather than panic, the family just laughed. The tiger was out of its lair, but its pathway was at a safe, meshed-in distance from onlookers, and after a few moments of looking around, the tiger moved on.

The tiger's trail, dubbed Big Cat Crossing, is part of a bigger initiative called Zoo360 that has changed the way humans and animals experience the nation's oldest zoo. Other Zoo360 features allow Philadelphia's white-faced saki monkey siblings to get some time away from mom and let lions take in scenery well beyond the exhibit where they

spend most of their days.

There's no question the experience is unique for the humans. On a recent visit, I watched children drop their lunches in awe of the white-faced sakis hanging out in the trees, witnessed one couple stop mid-conversation when a gorilla lumbered by overhead, and saw more than a few families startled by the appearance of a large cat. But the bigger impact of Zoo360, says the zoo's chief operating officer, Andrew Baker, may be its effort to transform the experience of animals in captivity. At a time when concerns about animal rights loom large, some experts believe this is what the zoo of the future will look like.

On the other side of the country, a different vision of the future is playing out. At Seattle's Woodland Park Zoo, the elephant exhibit, where countless children have watched pachyderms play, now sits empty. The zoo, long recognized as a world leader in innovative design, built a \$3 million state-of-the-art facility for the species in the 1980s. But in recent years, animal-rights advocates berated the exhibit as inhumane: too small, not reflective of the elephants' natural habitats.

Under pressure from activists following the death of an elephant in 2014 and new guidelines from the nation's main zoo organization, officials decided to close one of its popular exhibits and move the elephants.

"I am cautiously optimistic we'll be able to overcome this, but I'm not sure," says David Towne, who once oversaw the Woodland Park Zoo. "The animals-rights people have imposed their will on the elephants. I'm not sure that they aren't going to move on to gorillas, then other primates, and then what?"

Nearly two centuries after the first modern zoo opened in London's Regent Park, the very concept of a place where families can visit and observe animals is under pressure like never before. Across the U.S. and around the world, zoos are finding that a balance between entertainment, education and conservation is increasingly elusive.

Ethical concerns have been coupled with safety fears—both for people and for critters—following an incident in May when officials at the Cincinnati Zoo shot and killed a 17-year-old gorilla named Harambe to protect a child who had fallen into the exhibit. More broadly, there's a greater sensitivity to the environmental implications of zoos.

Ask a dozen zoo directors why these places should exist in 2016, and you'll find that opinions vary widely. Education, conservation and science all come up. But the most common answer—fostering empathy for animals—is becoming harder to do in facilities so much more restrictive than their natural habitats.

Study after study has shown that many animal species are far smarter—and more feeling—than previously understood, giving new insights into how they may suffer from anxiety and depression when they are removed from nature. That's forcing a difficult existential question: If we acknowledge that creatures suffer when they're confined, what is the future of animals in captivity? Not even those who have advanced the cause for more-humane exhibits have an answer. "Even the best zoos today are based on captivity and coercion," says Jon Coe, the legendary zoo designer who invented the Zoo360 concept for Philadelphia. "To me, that's the fundamental flaw."

“This moment at a zoo, where a person sees a gorilla look you back in the eye, helps them grasp their role in a greater natural world,” says Mike Clifford, who works in the Zoos and Aquariums studio at GLMV Architecture. Clifford’s job title is “curator of innovation,” but colleagues consider him their team’s chief philosopher: he’s charged with contemplating the difficult questions about the future of zoos. He thinks the answer lies in fostering human-animal connections—and making sure they also help sell tickets. That’s what GLMV has tried to do in Wichita, Kans., where visitors to the Sedgwick County Zoo can now ride in a boat to see the zoo’s elephants in their five-acre exhibit. The exhibit breaks down the barrier between animals and people while giving the elephants room to roam freely.

In Philadelphia, officials hope Zoo360 will provide those moments of connection, but they have also invested in other unusual ways of structuring their exhibits. Pigeons, rats and cockroaches may not qualify as exotic fauna, but they do occupy prime real estate.

Designers are also well aware of the need to address growing public distaste for animal captivity, however, which means more zoos are working not only to make their exhibits better suited for the animals but to also be able to demonstrate that to their visitors.

A good example is the St. Louis Zoo’s new polar bear exhibit, a \$16 million facility tailored to reflect the latest research about the animals’ needs. The 40,000-square-foot exhibit includes areas dedicated to each of the polar bears’ native environments: sea, coast and tundra. Designers built it spacious enough to accommodate up to five bears, allowing them to have a social environment. Finally, for any visitors still not convinced the bears’ best interests are at heart, the zoo has a 2,600-square-foot animal care facility where vets can tend to the bears’ health.

Pressure to develop state-of-the art exhibits means that most zoos will eventually need to reduce the number of animals they house. The footprint, and the cost, is simply unsustainable, several zoo experts say.

Consider the growing challenge of providing a home to elephants. A research consensus over the past decade suggests that most current exhibits are woefully inadequate. The most recent study—a comprehensive article published in the journal *PLOS One* in July 2016—shows how elephants thrive best when they have social connections and the challenge of having to gather their own food. When those factors aren’t present, elephants tend to have impaired mental states and do not carry out basic functions like reproduction. The study confirms what zookeepers have known for years. In fact, the Association of Zoos and Aquariums (AZA) approved rules in 2011 requiring any accredited zoo with elephants to keep at least three of the species and a full-time elephant scientist on staff, among other things.

But not every zoo has the space or budget to meet those guidelines. Some, such as the zoos in Omaha, San Diego and Houston, have doubled down with better facilities. Others—San Francisco, Seattle and Chicago, to name a few—have given up on keeping elephants entirely. (Other zoos, known derisively as “roadside zoos,” might keep elephants but lack certification from the AZA and largely fall outside the scope of this

story.)

On the human side of the equation, one thing remains clear: people still enjoy a chance to see and get close to animals. More than 170 million people visited accredited U.S. zoos in 2015, according to the AZA, up 10 million from two years earlier. “The business continues to change and evolve,” says David Walsh, who founded Zoo Advisors, a zoo financial consulting firm. But “people are still going to zoos. And they’re going in bigger numbers than they were before.”

Still, those numbers will do little to diminish the growing outrage of animal activists and, if cockroaches replace elephants, maintaining attendance levels will be a challenge. “Where are we going?” asks Towne, repeating my question. “I guess I’m worried.”



Enclosed trails at the Philadelphia Zoo allow animals to roam between habitats as part of Zoo360, a program that allows animals to wander freely, entertaining guests.

Visits to accredited zoos increased to more than 170 million in 2015, up 10 million from two years prior. The growth came despite growing concern

about the treatment of animals in captivity



Your Cat Doesn't Need You



Your cat doesn't really need you, a new study suggests. According to the study, in *PLOS One*, cats show little to no separation anxiety when they're away from their owner. When they do decide to stick around humans, it's because they want to.

Researchers studied the behavior of 20 cats placed in an unfamiliar location with their owner and with a stranger. The results suggest that our feline friends show few signs of distress when left alone in strange environments.

"Although our cats were more vocal when the owner rather than the stranger left them with the other individual, we didn't see any additional evidence to suggest that the bond between a cat and its owner is one of secure attachment," researcher Daniel Mills, a professor of veterinary behavioral medicine at the University of Lincoln in England, told the *Telegraph*.

The study, however, is small and relies heavily on interpretation. Cats display distress and emotion in a variety of ways—so perhaps your cat is different.

Whales Have Dialects as Humans Do



Whale researchers and enthusiasts have long known about the loud clicking sounds made by the marine mammal to communicate. Now new research shows how whales at different spots around the globe communicate with variations of the sound, an analogue to human dialects.

Researchers tracked groups of whales during a series of two- to four-week trips between 1985 and 2003, recording both images and sound. The study, published in the journal *Nature Communications*, suggests that the dialects emerged as a result of cultural learning similar to the processes that humans undergo.

These experiences and differences play a key role in the formation of culture and differentiate one group from another, according to the study. Still, the difference in dialects confounded researchers, given the lack of physical barriers in the ocean. “Providing evidence that the processes generating the complex and diverse cultures in human populations could also be at play in non-human societies is a crucial step towards evaluating the contrasts and convergences between human and non-human cultures,” researchers wrote.

Elephants Can Teach Us Something About Cancer



For many years, Joshua D. Schiffman, a researcher at the University of Utah, drove past Salt Lake City's Hogle Zoo on his way to work. But he had no idea that the animals inside, specifically elephants, might provide the answer to a puzzle he had been trying to solve: Who gets cancer and why?

In his new study, published in the journal *JAMA*, Schiffman and his colleagues argue that their recently gained insight into why elephants so rarely die of cancer could pave the way to a better understanding of the disease in humans.

Elephants have evolved to have 40 copies of the cancer-protective gene known as TP53, compared with just two in humans. TP53, as Schiffman and other scientists describe it, is the “guardian of the genome,” protecting us from cancer by encoding for the protein p53, a tumor suppressor.

The researchers took elephant and human blood and exposed the samples to drugs and radiation that cause DNA damage. They found that while the elephant and human cells repaired DNA at a similar rate, elephant cells underwent significantly more cell death—one way a body fights cancer.

Schiffman plans to use the findings to look into possible ways to get human cells to act more like an elephant's. For instance, he says, there may be drugs that already exist or are still unknown that can do it.

Tiger Populations Grow for First Time in 100 Years



Wildlife conservationists say the global tiger population grew in 2016 to the highest level since the start of the decade, marking the first rise in the tiger population count in nearly 100 years.

There are about 3,890 tigers in the wild, according to the most recent count. At the time of the last world count of tigers in 2010, there were an estimated 3,200 tigers in the wild.

The World Wildlife Fund (WWF) attributes the rise in its tiger count to an increase in population in India, Nepal, Russia and Bhutan. Better technology and improved protection efforts likely contributed to the species's recovery as well.

The tiger remains an endangered species despite the improvement. Tigers are constantly at risk of poaching and losing their habitat to deforestation, particularly in Southeast Asia.

Countries have pledged to double the global tiger population by 2022. The WWF says the new numbers suggest that conservation efforts are on the right track, even if a lot of work remains ahead.

“This is a pivotal step in the recovery of one of the world’s most endangered and iconic species,” said Ginette Hemley of WWF. “But much more work and investment is needed.”

Why You Should Fear an “Ecological Recession”



Sea turtles are one of many species whose decline has contributed to biodiversity loss.

Human efforts to slow biodiversity loss are falling short across the globe, which could in turn harm future human development and well-being, according to new research.

Researchers behind the study, published in the journal *Science*, found that changes in how land is used—the destruction of habitats, often for timber, agriculture or residential developments—have caused biodiversity to fall to unsustainable levels on more than half of the world’s surface. On average, human activity has driven away 15% of the species that would have been present otherwise in locations across the globe.

“Decision makers worry a lot about economic recessions,” said author Andy Purvis, a professor at the Natural History Museum in London. “But an ecological recession could have even worse consequences—and the biodiversity damage we’ve had means we’re at risk of that happening.”

Determining exactly what level of biodiversity loss can be sustained without damaging human well-being is difficult. Previous research has suggested that a decline of more than 10% in the number of species in a given geographical area could be dangerous, but even that figure is far from certain. Biodiversity plays a key role in a number of biochemical areas, including pollination and pest control, both of which support agriculture.

Dogs Can Understand Both What We Say and How We Say It



If you've ever thought your dog could understand what you're saying, you may have been right, according to new research.

Researchers in Hungary have investigated and recorded the brain activity of dogs, confirming that they not only understand the words we speak but also how we say them.

The new research, published in the journal *Science* and led by Attila Andics, a research fellow at Eötvös Loránd University in Budapest, reports that dogs can distinguish words and the intonation of human speech much as humans do.

For the study, dogs were exposed to recordings of the voices of their trainers, who spoke to them with a range of vocabulary and intonation in both praising and neutral ways. Andics and his colleagues then analyzed the canines' brain activity using an fMRI scanner, revealing that they could recognize each word as distinct, as well as the way it was said. The positive words spoken in a positive tone prompted the strongest activity in the brain's reward centers.

African Elephants May Not Recover from Poaching



African forest-elephant tusks, marked by poachers

African forest elephants are facing severe population declines because of poaching, and scientists now estimate that it will take almost a century for their population to recover.

According to a study by the Wildlife Conservation Society published in the *Journal of Applied Ecology* in 2016, it will take African forest elephants about 90 years to recover from the damage done by poachers. Between 2002 and 2013, the population of forest elephants in central Africa decreased 65%.

“The impact of these data is that forest elephants are facing a huge challenge in recovery,” says lead author Andrea Turkalo of the Wildlife Conservation Society. “If the poaching is not curtailed, they are faced with extinction sooner than we thought.”

Their recovery is expected to take such a long time because of elephants' slow birth rate. Forest elephants in central Africa begin breeding at about 23 years of age. After that, they reproduce only once every five or six years.

These Birds Choose Love over Food



Birds are willing to starve themselves to spend more time with their life partner, according to a new study.

Scientists at the University of Oxford discovered that some birds are willing to forgo food to stay near their partners during the winter months. The researchers used automated feeding stations to track the eating habits of great tits, a bird species. For each couple, one bird would be able to access only certain stations, while its partner was only able to access others. Researchers found, however, that one bird would end up spending much of its time at its partner's station even though it was locked out from accessing food there.

“The choice to stay close to their partner over accessing food demonstrates how an individual bird's decisions in the short term, which might appear suboptimal, can actually be shaped around gaining the long-term benefits of maintaining their key relationships,” said lead researcher Josh Frith.

These birds were also willing to spend extra time with their partners' flockmates, the study found. The results of the study were published in *Current Biology*.

HOLY COW!

Some Sharks Can Live for Hundreds of Years



If the *Mayflower* passed by a baby Greenland shark in 1620, and if sharks could talk, this one could still tell the tale. That's because, according to a new study in *Science*, Greenland sharks have just copped the award for longest-living vertebrate, with at least one who lived an estimated 400 years.

Greenland sharks, as their name suggests, favor the waters of the cold North Atlantic. They are a widely distributed species and among the bruisers of the shark world, measuring 13 to 16 feet at maturity.

In order to determine if the sharks are indeed as old as they seem, a team of researchers studied the remains of 28 female Greenland sharks, looking at the lenses of the animals' eyes. The shark's lens is formed in utero and contains radioactive carbon-14 that was extant at the time. That means that carbon-14 dating—how much has decayed since the lens of the eye was formed—can serve as an accurate marker of the animal's age.

The Earth

Fracking Earthquakes ■ Coral Reef Bleaching ■ Hot Nights and Heat Waves ■ Air Pollution Worsens ■ Antarctic Ice Melt ■ A Record-Hot February ■ A Honeybee-Killing Pesticide ■ Smog Chokes California ■ Climate Change's Illusory Side ■ Groundwater Bonanza

The New State of Earthquakes

Thanks to fracking and horizontal drilling, the once seismically calm state of Oklahoma has been hit by a wave of tremors

BY JOSH SANBURN



The oil and gas industry has been linked to a wave of earthquakes in Oklahoma.

Stillwater, Okla., resident Angela Spotts dreams of earthquakes. Not of her house falling through a crack in the earth or her walls tumbling down. She imagines them happening, their seismic waves buckling the red dirt plains outside. She often gets jolted awake at night, not knowing if she's feeling an actual quake or if it's in her mind. If it's real—and more often than not these days, it is—she looks at the clock, makes a note of the time so she can report it, and tries to go back to sleep.

In 2007, Oklahoma had one earthquake of magnitude 3—the lowest level at which they can usually be felt—or higher. In 2015, there were 907. The state now has more 3-plus earthquakes than California, and of the 12 largest tremors in the state's history, 10 have occurred since 2011. No place in the world has ever experienced earthquakes at such a rate in such a short time, let alone somewhere wholly unprepared for them. It's gotten so

bad that some are considering something more reminiscent of Tom Joad's time: leaving the state altogether.

At the center of it all is what virtually everything in Oklahoma has revolved around since statehood: oil and gas. The energy business indirectly accounts for 1 in 5 jobs around the state and roughly 10% of its GDP. Prominent buildings are named for oil and gas companies. The state's sports stadiums bear the names of energy firms and their billionaire founders. Even the state capitol sits atop a giant oil field, surrounded by pump jacks dipping their beaks into the earth below. Energy makes or breaks Oklahoma. And right now, it's breaking it.

Following years of denials, state officials finally acknowledged in 2015 what scientists had been saying publicly for some time: Oklahoma's transformation into a seismic hot zone is connected to its most important industry. From 2010 to 2014, oil production in the state nearly doubled and natural gas grew by almost 50%, according to the research firm RegionTrack. New drilling technologies made it possible to extract oil from sites once considered too watery, while the soaring price of crude made it worth the hassle. But it turns out that disposal wells, which inject back into the earth the salty wastewater that comes to the surface alongside oil and gas, have been lubricating the fault lines deep beneath the prairie floor, leading to earthquakes.

Yet state leaders have been hesitant to take any measures that might anger the energy industry. For years, the official line was that the quakes were naturally occurring. Some claimed, incorrectly, that the state had always had significant seismic activity. Others still say more research needs to be done. Even during this year's State of the State address, Governor Mary Fallin praised first responders in tornadoes, floods and blizzards. But when a legislator called out "And earthquakes!" the governor said, "I wasn't going to say that word, but thank you for reminding me."

The omission speaks to a larger point. For more than a decade, Oklahoma has been one of the biggest beneficiaries of America's oil boom. Two pioneers of the fracking revolution, Chesapeake Energy and Devon Energy, are headquartered in the state. As oil prices climbed above \$100 a barrel, Oklahoma's tax base grew, its unemployment rate fell, and the state even landed its first big-league sports team—the NBA's Oklahoma City Thunder.

But after its steady rise, the price of oil has fallen, briefly dropping to as low as \$30 a barrel, thanks to decreased demand and a global supply glut. And the downturn is being felt particularly hard in the Sooner State. Large energy companies have laid off thousands of employees. Smaller outfits are losing money on every barrel. Chesapeake—which put its name on the Thunder's downtown arena—lost 80% of its value in the past year. Businesses that depended on the sector are suffering as a result. Greco Motors, near Oklahoma City, said it has gone from selling one car a day to 12 a month.

The energy boom may be over, but the man-made geological mess it created has gotten worse. "You have scientists warning us that a big one is coming," says Spotts, who became a vocal industry critic when an oil well showed up within 900 feet of her house. "The more we shake, the worse it's going to get. It's coming."

South of the unincorporated township of Leonard, Okla., along Glasnost Road, sits what's left of the Leonard Geophysical Observatory, a series of mildewy structures filled with outdated seismographs and faded maps of the U.S.S.R. This, says Jerry Boak, the director of the Oklahoma Geological Survey (OGS), was the one place where earthquakes were monitored throughout the state—"until we started having all of this activity."

Historically, Oklahoma had about one earthquake a year, on a par with states like South Dakota and North Carolina. But the frequency ratcheted up as the oil boom took hold. By 2009, it had 20. The next year it had 35. Then on Nov. 5, 2011, around 10:53 p.m., an earthquake measuring 5.6 struck near Prague, a small town about 50 miles east of Oklahoma City. It was powerful enough to collapse a tower at a nearby college and was felt in parts of Arkansas, Kansas and Missouri.

The Prague earthquake was the strongest ever recorded in Oklahoma. The timing, many scientists say, was no coincidence. Fracking and horizontal drilling helped companies expand domestic oil and gas exploration in places like the Mississippian Lime, a carbonate rock formation thousands of feet below ground in north-central Oklahoma and south-central Kansas. Part of an ancient shoreline that ran through Oklahoma millions of years ago, the area had been only lightly drilled because it was filled with water, and it was too expensive to separate it from the oil and gas at the surface. But as the price of oil increased, energy companies now had the capability—and the financial incentive—to pull it out of even the most waterlogged formations.

Kyle Murray, an OGS hydrogeologist, says firms went from drilling 50 to 100 wells per month to up to 250 in 2015, with some wells producing 65 barrels of water for every barrel of oil. Alfalfa County, at the state's northern edge, jumped from producing 40 million barrels of wastewater annually to 200 million. In 2014, the entire state produced an estimated 3 billion barrels. Much of this water, which Boak describes as saltier than the Dead Sea, was then injected into the porous Arbuckle zone, a series of carbonate rock formations about 7,000 feet below the surface. It was thought to be the perfect candidate, Murray says, because it could accept the fluid and was far from freshwater sources.

Few realized, however, just how much pressure was building up in the Arbuckle, stressing fault lines in the crystalline basement rock below. Some seismologists liken the scenario to an air-hockey table. Imagine the puck and the table as two separate rock formations on opposite sides of a fault. When the air is off, the puck sits still. But turn the air on, and the puck begins to move because the friction is reduced. Those billions of barrels, says Art McGarr, a geophysicist with the USGS's Earthquake Hazards Program, reactivated faults that hadn't moved in 300 million years.

As quakes continue, many residents are learning that they're not covered for damage. The state's insurance department estimates that 15% to 20% of residents now have earthquake insurance, but it's typically catastrophic coverage, meaning homes often need to be lying in a pile for a claim to be successful. Most residents instead are dealing with the cumulative toll of dozens of smaller quakes.

“What pisses me off is that we’ve changed the assumption of risk to live in the state of Oklahoma, and we seem to be OK with it,” says state representative Cory Williams, a Stillwater Democrat whose bill requiring insurers to cover induced earthquakes failed in the legislature.

Even as the oil boom recedes, its dangerous legacy will remain. Earthquakes create their own momentum: the more magnitude-3 quakes you have, the more 4s; the more 4s there are, the more 5s—and Oklahoma is already on pace to have more 4s this year than in 2015. Some researchers worry about even-longer-term consequences. Daniel McNamara, a U.S. Geological Survey geophysicist, says he believes that if all disposal-well activity stopped today, the state might still have earthquakes for decades. “I have never seen anything like it and never read anything like it in history,” he says.

Living inside this new earthquake zone will be residents like Spotts. Last fall, she and her husband were sitting on the sofa when a 4.3 quake hit Stillwater. “It whiplashed us,” she says. “We looked at each other and said, ‘I don’t want to own a home anymore. How do we live here and grow old?’ ” They want to move but worry they won’t get enough for their home because of the quakes. “I’m not going to run from the fight,” Spotts says. “But I don’t know if I can live in it anymore.”

300 million Number of years since Oklahoma’s faults were last active,
before the recent earthquakes

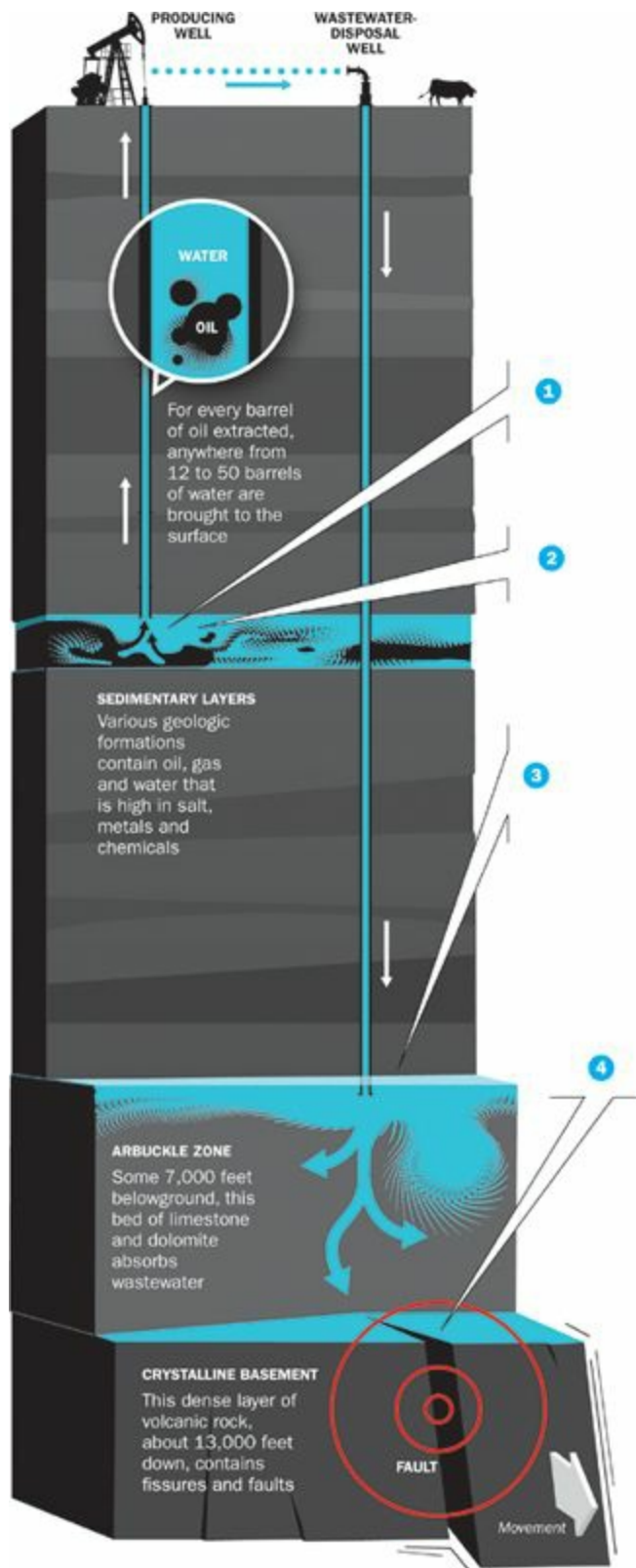
10 Number of earthquakes, of state’s 12 largest, that have occurred since
2011

0 Seismologists employed by the state

How the Quakes Are Triggered

See illustration on the following page

1. Oil and gas wells in Oklahoma extract large amounts of saltwater left over from ancient oceans.
2. Increased drilling activity in water-laden underground layers and advanced extraction technologies have recovered vast amounts of water in recent years.
3. The salty wastewater is pumped back into the ground below freshwater aquifers. Most of it is injected into the Arbuckle zone, which contains no oil or gas.
4. Friction generally keeps the sides of a fault clamped together. But water pressure reduces the fault's friction, causing it to slip and release energy as an earthquake.



Coral Bleaching Has Never Been This Bad



Researchers from the National Oceanic and Atmospheric Administration (NOAA) reported last summer that coral bleaching has hit a record level. And the report shows a 90% chance of continued bleaching in many parts of the Pacific Ocean and other areas near the coast of the U.S. because of high ocean temperatures disrupting coral ecosystems.

The ongoing bleaching event, the longest in recorded history, began in 2014 and has killed more than a third of the coral in some locations. “If you think of corals as canaries [in a coal mine], they’re chirping really loudly right now,” said Jennifer Koss, NOAA’s Coral Reef Conservation Program director, at a press conference. “The ones that are still alive, that is.”

Bleaching occurs when threats to coral ecosystems like pollution and unusually warm water cause the symbiotic organisms that give coral its color to flee. Some coral recovers from bleaching events—so called because they leave the coral reef bone white—but others die. Coral experts fear that continued climate change may cause more frequent and devastating bleaching events as temperatures rise in the coming years and decades.

The El Niño phenomenon, characterized by unusually high ocean waters in the equatorial Pacific, exacerbated coral bleaching over the past year. NOAA said reefs would get little respite when El Niña, the opposite phase of El Niño, hit at the end of 2016. La Niña brings high ocean temperatures to the western Pacific, along with a slew of other effects.

AS MUCH AS **35%** OF THE CORAL DIED IN SOME REGIONS OF THE
GREAT BARRIER REEF

Why Hotter Nights Make Heat Waves Dangerous



Summer 2016 was the fifth-hottest on record (tied with 2006) for the continental U.S. Nighttime should offer natural relief for those without artificial cooling, when the sun disappears and temperatures drop. But that doesn't work if even the low temperatures stay high. "When it's hot out, your body has to work pretty hard to keep itself cool," says Brooke Anderson, an epidemiologist at Colorado State University. "If it gets very hot at night and you continue to be exposed to it, your body does not get a chance to rest."

In recent decades, nighttime temperatures have increased at a faster clip than daytime highs in the U.S. Scientists attribute the overall temperature rise to human impact, but they are less sure about why nighttime temperatures are increasing faster. Some scientists have suggested that it may be related to increased cloudiness, which locks hot air close to the Earth's surface. Others suggest it could be the result of agricultural land-use changes that have resulted in increased irrigation and, in turn, increased humidity.

Addressing the issue, as well as heat waves more broadly, poses a difficult challenge for policy makers. Deaths from extreme heat often draw less attention than flooding or more-dramatic events like hurricanes. Experts say that in the short term, people need to turn on their air-conditioning or go to a cooling center. But the problem will only get worse—and it could get a lot worse—without addressing man-made climate change.

Global Air Pollution Is on the Rise



More than 80% of the world's urban population lives in areas where air quality does not meet standards set by the World Health Organization, according to a 2016 report. The report, which looks at levels of small but damaging pollutants known as particulate matter, suggests that global urban pollution levels increased by 8% in the five years preceding 2013. That increase hit poor countries particularly hard.

Crippling air pollution in a few cities—Beijing, Mexico City, New Delhi—has attracted global media attention. But 98 of 100 cities in low- and middle-income countries do not meet air-quality standards. The number declines to 56% in wealthy countries, but cities like London, Paris and Rome still make the list of places that do not meet the standards.

“Air pollution is a major cause of disease and death,” says Flavia Bustreo, an official at WHO. “When dirty air blankets our cities, the most vulnerable urban populations—the youngest, oldest and poorest—are the most impacted.”

The health effects of air pollution come under increasing scrutiny as study after study has shown that the problem contributes to millions of premature deaths each year. Air pollution has been linked with a number of ailments, including decreased lung functioning, asthma and cancer.

Ice Melt in the Antarctic May Be Worse Than Scientists Thought



Melting ice from one of Antarctica's largest glaciers, a result of climate change, could raise global sea levels by more than six feet. A 2016 study, published in the journal *Nature*, relies on data on past ice levels of the Totten Glacier in East Antarctica to evaluate the rate of melting. Without intense efforts to stem human-abetted global warming, the glacier's melting process could cross the point of no return within the next 100 years, according to the report. The result would add more than 6.6 feet of sea-level rise over the coming several centuries, in addition to several feet of rise from other sources.

The contribution of ice melt to sea-level rise is the topic of frequent attention from academic researchers, but most studies of Antarctica have focused on the more vulnerable western part of the continent. Another study published in *Nature* this year shows that global sea levels may rise 3.5 feet by the end of this century and 40 feet by 2500 without action.

Sea levels rose more than five inches during the 20th century, faster than at any time in the previous 2,800 years, according to recent research. And while a few inches—or even a few feet—may not sound substantial, higher sea levels will contribute to increased flooding during storms and at high tide far before they completely sink the world's many coastal cities.

March 2016 Had the Most Above-Average Temperatures on Record



Global temperatures in March 2016 broke the record for the most above-average since weather record-keeping began nearly 150 years ago. This brought the world the closest it has ever been to what scientists consider dangerous levels of warming, according to NOAA. The previous month, February 2016, also saw above-average temperatures, only slightly below those from March.

The average temperature across the globe in March was the highest it's ever been for that month since recording began, in 1880. It was 2.2°F higher than the 20th-century average. Most scientists say a rise of 3.6° above the global temperatures before humans began putting large amounts of carbon dioxide into the atmosphere as the point at which the effects of global warming become irreversible: when Arctic ice will melt at an unsustainable rate, and some island countries will begin disappearing into the ocean.

The 3.6°F (2°C) marker has also been enshrined into public policy and international climate deals, including the Paris Agreement, as a level that should not be exceeded. The March temperature record suggests that it may be harder to meet that target without a dramatic acceleration in efforts to reduce global carbon emissions.

This news came as research from the National Academy of Sciences emerged, showing that climate change contributes to extreme weather events like drought and flooding. And although the exact link between climate change and weird weather remains unclear, unusually mild months like February and March raise the risk that the world will be

caught off guard by extreme and unexpected weather events.

This Common Pesticide Is Reducing Sperm in Bees



A commonly used pesticide is making it harder for bees to reproduce, reducing sperm count and viability, according to new research.

The study, published in the journal *Proceedings of the Royal Society B*, joins abundant research showing how neonicotinoid pesticides have harmed bee populations, increasing their vulnerability to disease. The lower number of bees has agricultural producers and policy makers in the U.S. worried. Dozens of commercial crops that contribute billions of dollars annually to the economy rely on pollinators like bees, according to a White House report.

The new research focuses specifically on male bees and shows that drones in colonies exposed to neonicotinoids have produced 39% less live sperm than their non-exposed counterparts. “Male honeybees have really been neglected by honeybee health scientists,” says study author Lars Straub, a researcher from the University of Bern in Switzerland. “These results may turn a few heads.”

The European Union previously banned neonicotinoids, and they are under review by the EPA.

Smog Is Getting Worse in Southern California



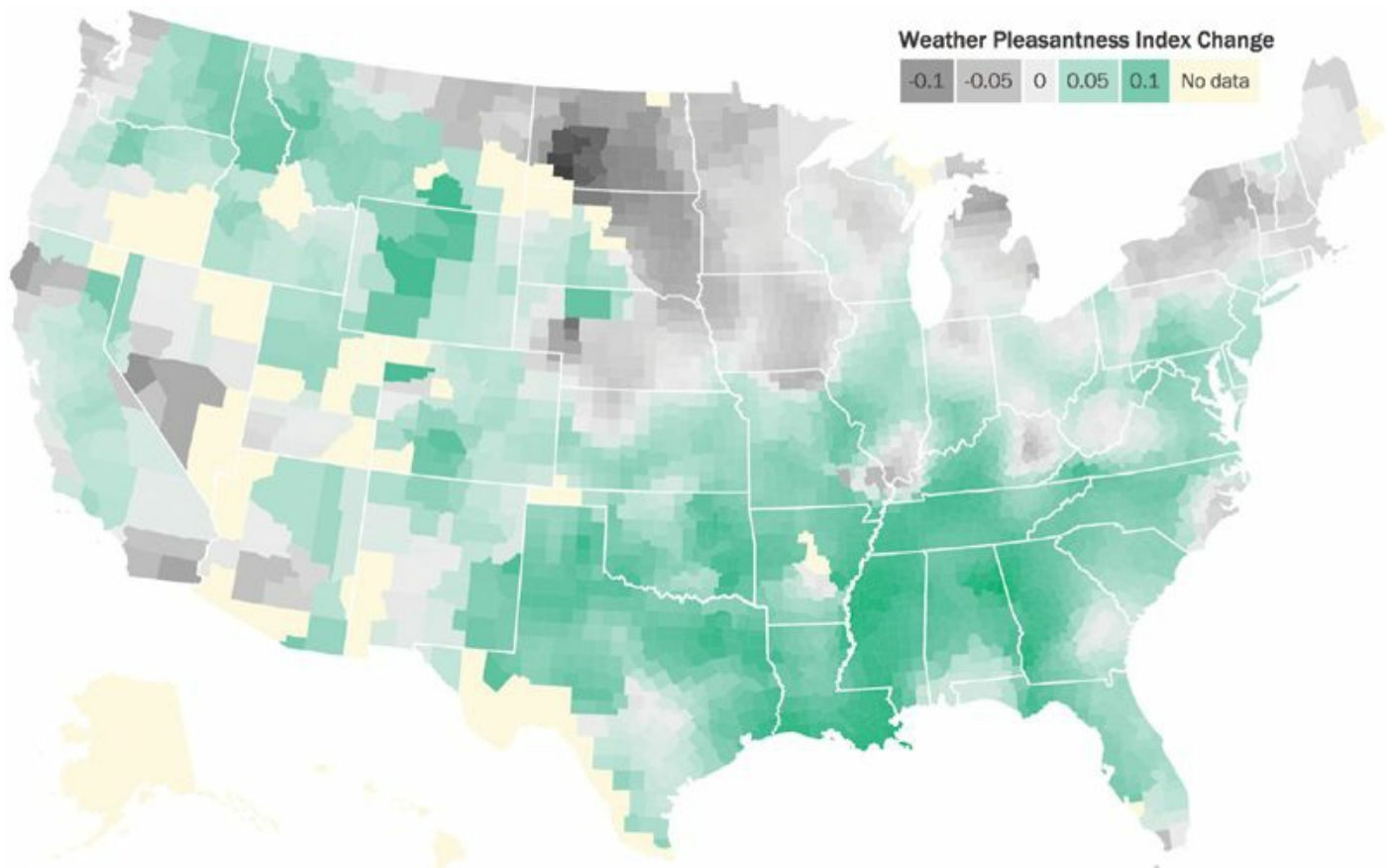
The worst smog in years inundated southern California in the summer of 2016, driving people to hospitals and health clinics for treatment of respiratory illness.

Some of the warmest weather of all time, compounded by stagnant winds, worsened the problem, the report said. Ozone levels topped federal standards on 91 days through summer 2016, compared with 67 days in 2015.

Policy makers in developed countries have implemented a number of regulations to improve air quality in recent decades, leading to a dramatic decline in air pollution. But that progress has slipped in some places in recent years for a variety of reasons. Rising temperatures in Southern California—due to climate change, El Niño and assorted other factors—have heated hydrocarbon and nitrogen oxide pollution from vehicles, leading to smog. Storms typically clear the air, but they have been in short supply during the state's drought.

California is not the only place with an air-pollution problem. In many European cities, an increase in the number of diesel vehicles has worsened air quality. Developing countries like India and China continue to experience high levels of air pollution as a result of rapid industrial growth and weak regulation.

Climate Change Has Been Making Weather Nicer—and That’s a Problem



Climate change has actually improved weather in the U.S. over the past several decades, but that will not last, with pleasant weather substantially diminishing by the end of the century as the globe continues to warm, according to a study in *Nature*. Researchers say the study shows why the rising temperatures that are part of climate change may deter people from taking action on warming. It may be hard for Americans to see climate change as potentially catastrophic when in the short term it has improved day-to-day weather.

“Scientists tend to say, ‘Look, temperatures are rising,’ but to a lot of the public that doesn’t carry a sense of alarm,” says study author Megan Mullin of Duke University. “In fact, that may come as good news.”

Previous research shows that most Americans appreciate warmer winters and dislike hot and humid summers. The *Nature* study showed that 80% of Americans live in places that receive better weather than 30 years ago. That’s because winters have so far been warming more than summers have, so Americans have gotten to enjoy less-cold winter months without—so far—having to experience unusually hot summers.

HOLY COW!

Scientists Find Water Underground in California



Part of the solution to California's demand for water in the face of crippling drought may lie up to 10,000 feet beneath the surface of the state's Central Valley. Research published in the journal *PNAS* suggests that the region's aquifers, areas deep underground where water can collect, have three times as much usable groundwater as previously estimated. Researchers behind the study say their work underscores the need for state officials to monitor oil and gas extraction that could contaminate an important, if untapped, resource. Nearly a third of oil and gas drilling sites are located near groundwater reservoirs, threatening the potability of the water, according to the study.

While the study offers a potential solution, extracting water from such depths would not be easy. Deep drilling is costly, and much of the water would likely be brackish, or salty, and require the construction of desalination facilities.

The Mind

How to Prevent Alzheimer's ■ Red Wine and Brain Aging ■ Exercise Beats ADHD ■ Club Drugs For Depression ■ Brain Games That Work ■ Mental Health Genes ■ Phones Linked to Cancer ■ New Hope for Stroke ■ Your Brain on Magic Mushrooms ■ How Hypnosis Heals

Untangling Alzheimer's

When it comes to preventing cognitive decline, simple lifestyle changes are finally being borne out by science

BY MANDY OAKLANDER



Majid Fotuhi built his first brain out of wood and foam. It was the best way, he thought, to help his fellow students at Harvard grasp how complex and beautiful the organ is. Fotuhi hired a pair of art-school students for the summer of 1993 and, millimeters at a time, they sketched a dead human's brain, which Fotuhi schlepped back and forth between the neuroanatomy lab and an art studio across campus. By the time classes started that fall, they had turned their sketches into a five-foot-high replica that hinged open to reveal hundreds of discrete parts, including some purple blood vessels and a peach-colored cortex.

Decades later, Fotuhi, now a neurologist who specializes in the prevention of Alzheimer's disease, remains intent on the organ. "It's not this mysterious black box sitting up there, disconnected," he says. "It's tightly, tightly connected to the rest of the body, and you can take care of it the same way you can take care of your teeth."

Fotuhi has long believed that doing just that—taking care of the brain as well as you take care of the rest of your body—can stave off cognitive decline. For most of his career, that thinking put him in the minority; neurologists, stumped by Alzheimer's, have focused their efforts on trying to find a cure for the disease. They have made progress, but doctors do not yet have a reliable way to treat dementia with drugs. At this rate, Alzheimer's disease and other dementias are expected to cost the U.S. \$1 trillion annually in health-care costs by 2050.

That projection is dire, but a glut of new research presented at the Alzheimer's Association International Conference in 2016 suggests that a path paved by reasonable lifestyle choices—including exercise and targeted brain training—may indeed protect the brain as it ages.

People have long puzzled over what causes some people to lose their mind in old age. In ancient times, dementia was believed to be an inevitable part of aging. Now it's mostly blamed on Alzheimer's disease. Experts still don't know exactly what causes Alzheimer's, but in 1992 one idea, called the amyloid cascade hypothesis, took hold. It suggested that the excessive buildup of a protein in the brain—amyloid, which clumps together into plaques—is the main driver of Alzheimer's. The buildup causes another protein, tau, to twist into tangles and cut off the supply of nutrients to brain cells, ultimately killing them. This hypothesis propelled the search for a pill that can stop these plaques and tangles from forming or undo them once they're there.

The overproduction of amyloid is thought to be a cause of early-onset Alzheimer's, which can affect the brains of people in their 40s and 50s. Little if anything can be done to prevent early-onset Alzheimer's, although it is an active area of research. But when it comes to the Alzheimer's that most people think of—a disease of the elderly that causes confusion and memory loss—there is a lot that experts still do not agree on, including whether the single-minded focus on amyloid and tau has been right.

Scientists like Fotuhi like to point out that plaques and tangles are sometimes found in the brains of people who don't have symptoms of dementia. Researchers in this camp often cite a story about Sister Mary, a tiny, social nun born in 1892 who taught until her death at age 101. In a 1980s study of the lives and deaths of almost 700 elderly nuns, an autopsy revealed that Sister Mary's brain was so full of amyloid plaques and tau tangles that she met the criteria for Alzheimer's disease. Yet in life, her mind was reportedly sharp until the end.

Other research has suggested that amyloid isn't enough to explain all—and possibly even most—Alzheimer's cases. A 2015 article published in the journal *Nature Neuroscience* made the case for rejecting the entire amyloid cascade hypothesis. Meanwhile, other factors—such as heart health, sleep quality and physical activity—are emerging as potential ways to help prevent dementia in some people.

By taking factors like these more seriously, scientists are forming a whole new Alzheimer's attack plan: improve the health of the heart and you'll have a big impact on the brain. Lifestyle changes won't ever eradicate the disease. But they may be the best prevention we know of right now.

In an article published in *The Lancet Neurology*, researchers projected that almost a third of the cases of Alzheimer's disease worldwide—9.6 million of them—could be prevented by things that are within most people's power to change: hypertension in middle age, diabetes, obesity, physical activity, depression, smoking and low education were all found to play a role.

Of these factors, heart health seems to be the most important. According to an estimate published in the journal *Hypertension*, if every middle-aged American with high blood pressure got properly treated for it, about 25% of dementia cases would be wiped out.

The link between the heart and the brain is logical when you think about it. "The brain is a sea of blood vessels," Fotuhi says, and because neurons require a lot of oxygen to fire properly, the brain uses 20% of the blood pumped by the heart. "For that reason, anything that affects blood flow affects the brain." When people have hypertension, obesity or Type 2 diabetes, the blood vessels don't work as well, the flow isn't as good, and the neurons become thirsty for oxygen.

Because heart disease is the No. 1 killer of Americans, experts have focused their advice on heart health for the past 30 years, and today the rates of death from heart disease and stroke have declined. Researchers are now beginning to see a link outside the lab between stronger hearts and healthier minds. One 2016 study in the *New England Journal of Medicine* dug into data from 5,205 people age 60 and older who are part of the Framingham Heart Study, which has tracked dementia in its participants since 1975. Over the 30 years of data, the incidence of dementia in people with at least a high school diploma fell by 44%.

"We think heart-disease risk factors have a big effect on brain health," says Kristine Yaffe of the University of California, San Francisco, a leading researcher on predictors of dementia. "Lifestyle factors are so important, even though they sound sort of soft and a lot of people therefore think they can't possibly be that effective. But I'm not so sure. They're not expensive, they don't have side effects, and they're good for the rest of the body too. So why wouldn't you make lifestyle changes?"

These natural interventions seem to have powerful effects on some parts of the brain that are vulnerable to aging. Consider the hippocampus, crucial to memory and one of the first regions of the brain to shrivel when people age. A smaller hippocampus helped researchers predict who would develop Alzheimer's disease in some studies. This brain region can also grow, however, through interventions such as exercise and meditation.

Dementia appears to plant its roots in the brain decades before diagnosis, so many leaders in the field are looking for ways to detect it at the onset of the disease, rather than after problems start. Yet it's never too late to adopt a healthy lifestyle. A study presented at an Alzheimer's Association conference showed that even sedentary elderly people with mild cognitive impairment can improve their brains by exercising.

At Fotuhi's neurology practice in Virginia, the NeuroGrow Brain Fitness Center, he gives patients cognitive tests to see their strengths and weaknesses, then puts them through a three-month boot camp that costs \$6,000 to \$7,000, depending on insurance coverage. People are encouraged to exercise, meditate, eat a Mediterranean diet, reduce

stress and improve their sleep. They also play brain games that are tailored to their weaknesses, go through cognitive behavioral therapy and have sessions of neurofeedback, a technique that lets patients modify their brain activity in real time.

Fotuhi and his colleagues tallied the effects in the *Journal of Prevention of Alzheimer's Disease*. Of 127 older patients with mild cognitive impairment, 84% showed improvement in at least three areas of cognitive function. Of the 17 who had an MRI before and after the study, eight had some shrinking or no growth in the hippocampus, but nine saw theirs grow by at least 1%. Fotuhi says he's taking his program nationwide.

It is still too early to know if interventions like these prevent Alzheimer's disease in the long run. But there is at least a suggested path. "My prediction is that one day, hopefully, Alzheimer's will be handled like cardiovascular disease," says Yaffe, "with a combination of drugs and lifestyle factors."





These lifestyle changes may help protect the brain as you age

1. SHORE UP YOUR HEART

Of all the things you can do, reducing the risk of heart disease has the strongest evidence of benefits for the brain. That means treating hypertension, high lipids, cholesterol, obesity and Type 2 diabetes.

2. EMPHASIZE EXERCISE

Physical activity reduces the risk and severity of cognitive decline. Aerobic exercise has been shown to grow the volume of certain brain regions that tend to shrink as we age.

3. CHALLENGE YOUR MIND

Engaging intellectually with the world across a lifetime through activities like writing letters and reading has been linked in brain autopsies to better cognitive health in old age.

4. BE SOCIABLE

Richer social lives are associated with higher levels of cognition. Loneliness, conversely, is connected with poorer brain health.

5. TREAT DEPRESSION

Depression in middle age—which is when it is most prevalent—is linked to twice the risk of cognitive decline, though it's not clear if that's a cause or an effect.

6. SLEEP WELL

Studies have found a relationship between poor sleep and risk of cognitive decline and Alzheimer's. Improving poor sleep appears to reduce these risks.

Could Wine Be a Foil for Alzheimer's?



Resveratrol, found in red wine and dark chocolate, may keep Alzheimer's disease from progressing. In a study published in *Neurology*, researchers created a purified form of the compound, which is being studied for preventing age-related conditions like diabetes and cancer. The researchers gave adults with mild or moderate Alzheimer's disease up to 1,000 milligrams of resveratrol or a placebo every day for a year, testing their cognition and independence along the way.

Those who took resveratrol had no change in the levels of a protein that builds up in the brains of Alzheimer's patients. They were slightly better able to do certain daily activities on their own, like dressing and bathing.

Red wine, of course, is not a cure for Alzheimer's, and resveratrol's role isn't yet clear. The purified doses in the study were far higher than anything currently on the market. More studies are needed to determine if resveratrol really has a benefit and if it can be turned into a more effective drug to better target Alzheimer's.

Exercise Does More Than Make You Fit

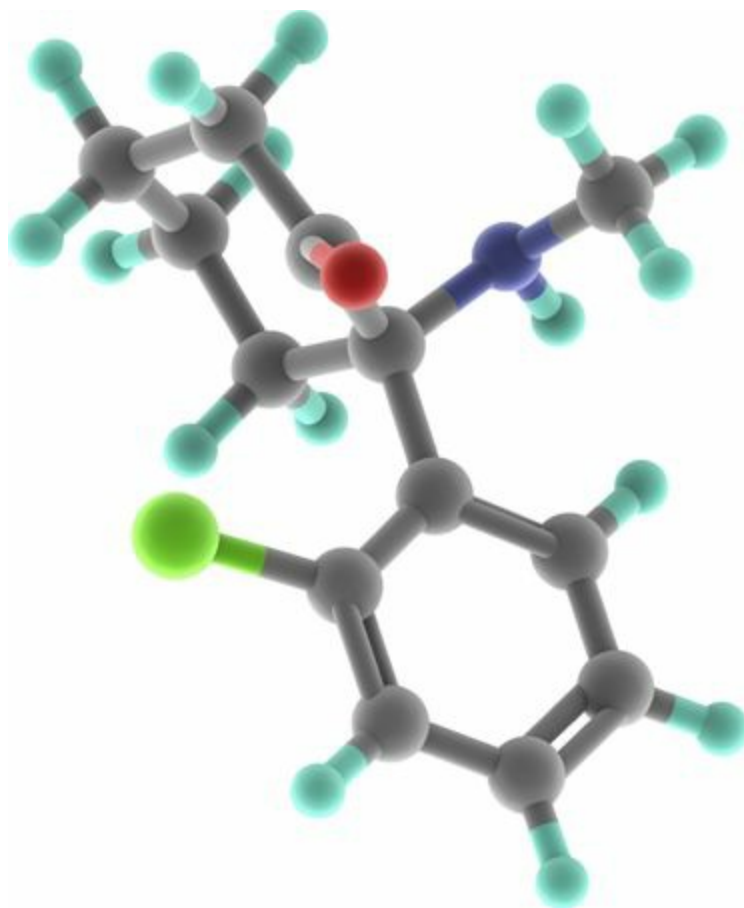


Breaking a sweat is a drug-free way to improve mood and make you feel better fast. New evidence comes from a study published in the journal *Medicine & Science in Sports & Exercise* in which researchers assigned 32 men who had reported having symptoms of ADHD to either sit or bike for 20 minutes. The researchers thought exercise might behave like a stimulant medication does in the brain, giving an extra dose of energy.

Indeed, exercising did enhance motivation and overall energy levels. The men also reported fewer feelings of fatigue, depression and confusion after they exercised. It didn't have an effect on cognitive abilities or levels of hyperactivity, but exercise didn't increase feelings of hyperactivity, either. The researchers say their findings encourage more research on non-pharmaceutical ways to reduce ADHD symptoms.

The study supports the idea that exercise is medicine and that it adds far more than fitness and muscle mass to the body. Given the high number of people in the U.S. who don't get enough physical activity, exercise should be a first-line treatment for mental as well as physical issues, experts say.

The Club Drug Ketamine May Treat Depression



A byproduct of ketamine triggered antidepressant effects.

Scientists are increasingly convinced that ketamine, a popular “club drug,” may be a viable treatment option for people who suffer from depression.

In a small study in the *Journal of Clinical Psychiatry*, 14 people with depression and suicidal thoughts were given a few infusions of ketamine—which is approved by the Food and Drug Administration as an anesthetic and for treating certain types of pain—and saw that their symptoms lessened considerably after three weeks. Another 2016 study published in the journal *Nature* used animals to see how ketamine works in the brain to affect depression. It found that while the drug itself led to dependence, one of ketamine’s byproducts, metabolites that it releases after it’s broken down by the body, triggered the antidepressant effects of ketamine without the side effects and addictive potential.

Larger trials are needed, and the side effects and long-term consequences of the drug must be evaluated. But if drug developers can find a way to mimic the metabolite, and provide it in just the right dose, ketamine could become an appealing treatment.

Brain Training May Help Fight Off Dementia



In the most rigorous study on the topic to date, researchers compared different types of cognitive training and concluded that one strategy—brain training that helps the mind process information quicker—can significantly lower rates of cognitive decline and dementia. The study involved about 2,800 healthy older people in a five-week training program. They were assigned to either no intervention or one of three tracks: improving memory skills; boosting reasoning skills; or a computerized program that focused on processing speed. Participants were then followed for 10 years. By the end, only those who did speed-processing training showed improvement: a 35% lower rate of dementia or cognitive impairment, even with no additional training, compared with those who received no training at all.

The program used in the study, created by a researcher at the University of Alabama at Birmingham, was purchased by Posit Science, a company marketing commercial brain-training programs. It developed an updated version, which is available online or as an app called BrainHQ for \$96 for a year. For now, it's the only one of its kind on the market—although if additional research proves promising, others will likely follow.

New Clues to Depression Spotted in the Genome



Depression is so hard to fight because we know so little about its source. Now, a big step: a study in *Nature Genetics* has revealed no fewer than 15 discrete regions on the human genome associated with the development of major depressive disorder.

The study involved nearly 460,000 subjects—conducted by researchers from Massachusetts General Hospital, Pfizer and 23andMe, the commercial genetic testing service. Researchers analyzed genetic profiles and looked for single nucleotide polymorphisms (SNPs)—or irregularities at specific points in the genome—that the depressive people shared but the non-depressive ones did not. In all, the investigators found 15 different SNPs located on parts of the genome related to the workings of the brain. One affects a region involved in the governing of memory, fear and anger, and others were found on parts of the genome that have been linked to epilepsy, panic attacks, and reported use of sleeping pills and pain medications.

The information may one day be used to develop more finely targeted drugs that can adjust neurotransmitters in more precise ways or to identify at-risk people long before the onset of the disease and pharmaceutically treat specific areas of the brain. The results help us better understand depression and could lead to novel ways to defeat it at last.

Cellphone-Cancer Link Has Been Seen in Rats

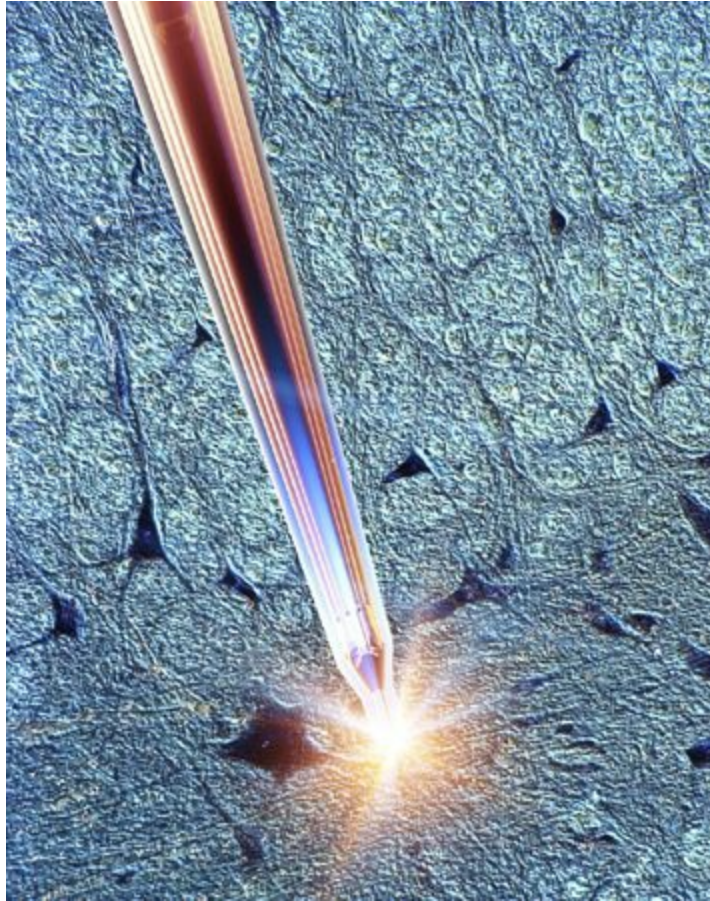


A recent government study performed on rats linked cellphone radiation to cancers of the brain and heart. The research, conducted by the National Toxicology Program, exposed rats to radio-frequency radiation from cellphones for about nine hours a day, seven days a week. At the end of the study, exposed rats were more likely to develop cancers, specifically malignant gliomas—a tumor of glial cells in the brain—and tumors in the heart.

Studies of rats are never directly translational to humans, of course. They do, however, give researchers evidence that can lead to further research on how humans may be affected. So far, observational studies in humans show limited evidence of cancer risk, though the World Health Organization says there's not enough research yet to rule it out.

This study is not the final word, and more research is expected to be released in fall 2017. Until then, those who are concerned can use headsets and turn off Wi-Fi when it's not in use.

There's Hope for a New Stroke Treatment



Deep brain stimulation has many applications.

Each year, half of the 800,000 Americans who have a stroke end up disabled. Doctors at the Cleveland Clinic hope to change that by applying deep brain stimulation (DBS), in which electrodes that give small electric pulses are implanted in the brain to help people disabled by stroke recover control of their movements.

DBS has been used to treat the tremors of Parkinson's disease. But for stroke, the goal goes beyond treating symptoms to making movement come back. Neurosurgeon Andre Machado, who is leading the trial, and his team have found that rats that experienced strokes but received DBS had more proteins in their brains linked to brain plasticity and twice as many connections between nerve cells as rats that experienced strokes but didn't get DBS. The team expects to perform the procedure in a stroke patient for the first time in 2017.

The Secret of How Hypnosis Really Works



The trance-like state of hypnosis can be an effective tool against pain, anxiety, smoking, stress and trauma, research shows. Exactly how is what David Spiegel, the director of the Stanford Center on Stress and Health, wanted to find out in a recent study.

Spiegel and his colleagues looked at brain scans of 36 highly hypnotizable people when they were under hypnosis. There was a drop in activity in the salience network of the brain, which determines what you can and can't ignore. Certain parts of the brain also began syncing up, suggesting that "your brain in hypnosis is intensifying its connection to your body," Spiegel says. Other areas became less connected, indicating lower levels of self-consciousness.

These changes help explain how hypnosis can have powerful effects. "It's a real-deal treatment that should be given the same respect as a lot of other treatments we use," Spiegel says, "that are sometimes less efficacious and more dangerous."

HOLY COW!

The Potential Power of Magic Mushrooms



Scientists are testing whether psilocybin, a psychedelic drug that promotes hallucinations and reduces inhibitions, can treat depression and anxiety. In a landmark pair of studies published in the *Journal of Psychopharmacology*, researchers gave 80 people with cancer-related depression or anxiety a single dose of psilocybin (known as magic mushrooms). In the studies, 60% to 80% of people reported reductions in their depression and anxiety symptoms that lasted six months after the treatment. In one of the studies, 83% of people reported increases in their well-being and life satisfaction, and 67% said the trial was one of the top five most meaningful experiences in their lives.

The study authors say that the drug may activate parts of the brain that are affected by serotonin, which can play a role in anxiety, mood and depression.

More research is needed, but psilocybin—given in the right dose under trained supervision—shows therapeutic potential.

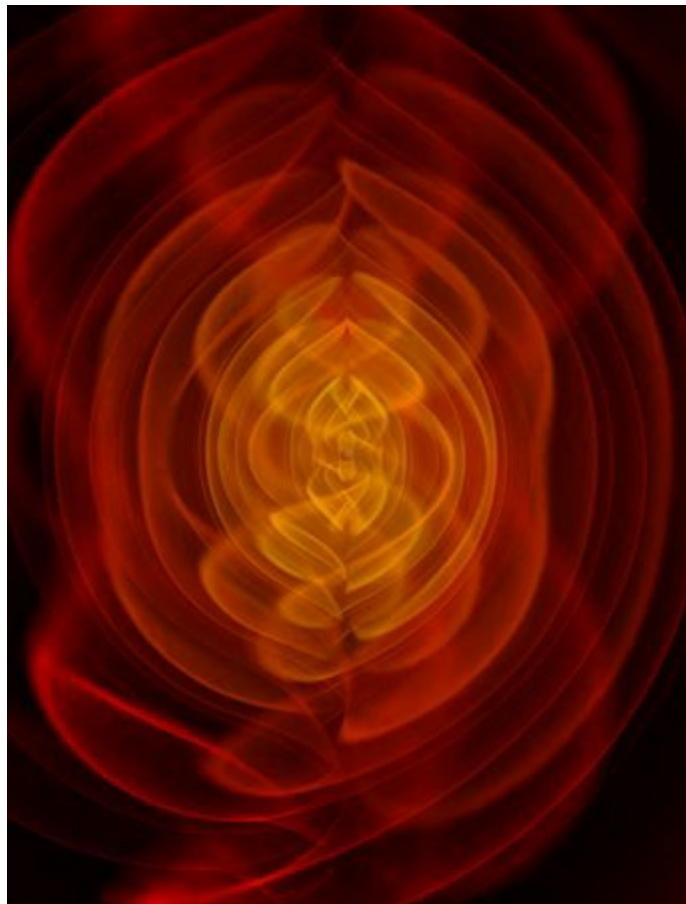
The Cosmos

Gravitational Waves ■ Black Holes ■ Earth-Like Planet ■ Jupiter's Auroras ■ "Morse Code" on Mars ■ 1,284 New Planets ■ 4-Billion-Year-Old Galaxy ■ A Watery Venus ■ Electric Wind ■ Journey to a Star

Gravitational Waves Are Confirmed

A century after Einstein predicted it, a force that literally shakes the universe is spotted

BY JEFFREY KLUGER



Computer simulation of two black holes colliding; gravitational waves billow outward.

The black holes that collided in space 1.3 billion years ago weren't aiming their energy at Louisiana and Washington State. That's a good thing, because Louisiana and Washington weren't there. The land that would one day constitute them existed in some form, but it was squashed into an early supercontinent that would need hundreds of millions of years to fracture and drift into the spots the states occupy today. And as for the people in Louisiana and Washington who would also be in the path of the energy? They were about 1.3 billion years in the future too. If life was present at all on those two patches of proto-land, it was single-celled.

And yet on Sept. 14, 2015, at 5:51 a.m. EDT, they all came together—the people, the energy, the modern states—and with that, everything changed. The blast released by the two black holes that once existed far from Earth moved toward our planet, stretching

and compressing spacetime itself until they fleetingly stretched and compressed Earth itself—perturbing a set of mirrors in two observatories in Hanford, Wash., and Livingston, La., causing them to move a distance equivalent to one ten-thousandth the diameter of a proton. The on-site computers spotted the motion, and the scientists in both places read the data and declared victory in the century-long hunt for gravitational waves, a phenomenon first postulated by Albert Einstein in 1916.

“We did it!” exulted David Reitze, a physicist at the California Institute of Technology and the director of the project, at a press conference announcing the findings on Feb. 11, 2016. “This was truly a scientific moon shot, and we did it. We landed on the moon.”

In some ways, at least to hear the physicists tell it, it was much bigger than a moon shot. The detection of gravitational waves answered one of the oldest and most stubborn questions in physics. It was an answer many people thought would never come.

From the beginning, Einstein’s theories about the mutability of time, space and matter required people to look at the universe in a new way. Rather than a great void in which massive bodies hang suspended, it is more like a distortable fabric, capable of warping and vibrating when disturbed. Drop a bowling ball on a trampoline, and the surface will bounce and then sag under the weight. Spacetime behaves similarly in response to massive objects like stars—though since there’s no up and down in space, it warps in all directions. Vibrations in the fabric are what Einstein called gravitational waves, a form of energy that ought to be every bit as real as electromagnetism.

But “ought to be” is not the same as “is,” and while it’s easy to observe electromagnetism—lightning will make the case quite nicely—the spacetime ripples are harder to spot. Einstein himself later had doubts, writing a paper in 1936 confessing that he might have been in error. But other scientists had more faith in the great man of physics than he did in himself and set out to prove it.

In 1969, physicist Joseph Weber of the University of Maryland claimed that he had confirmed the existence of gravitational waves with a detector of his own devising. It consisted of tubes of exceedingly pure aluminum about six feet long and three feet wide, with tuning-fork-like instruments inside. Perturbations from colliding bodies like neutron stars, he theorized, would set spacetime humming and subsequently set the forks buzzing. Eventually he indeed got a hit, recording a disturbance of just the proper frequency and fleeting duration. Other researchers, however, could not reproduce his findings, and Weber’s work would forever be seen as a nice try and a near miss but not the big find that he died, in 2000, still believing it to be.

American astronomers Joseph Taylor Jr. and Russell Hulse came closer to sealing the deal in 1974, when they observed a pulsar orbiting a neutron star and noticed that its orbit was steadily decaying. That meant it had to be losing energy, and their conclusion—all but certainly correct—was that it was losing it in the form of gravitational waves. They won the 1993 Nobel Prize in Physics for that discovery, but it was still only inferential work. The gravity waves themselves had not been detected.

The system that put the final piece in place in 2015 is known as LIGO, for Laser Interferometer Gravitational-Wave Observatory, dreamed up by physicists Kip Thorne

of Caltech, Rainer Weiss of MIT and Ronald Drever, formerly of Caltech. There are actually two LIGOs—one at each of the sites—both of which consist of an L-shaped pair of hollow steel arms, 2.5 miles long. An arrangement of mirrors bounces laser light up and down the hollow interior of the arms, with the beams in each one in perfect synchrony with those in the other. There is a lot that could knock the beams out of rhythm—including footsteps by the scientists tending the instruments, micro-tremors in the Earth or even the rumble of traffic many miles away. Shock absorbers cancel nearly all of that out, and computers learn to disregard the rest. Should any lingering disturbance somehow slip through, the 1,900-mile distance between the two sites ensures that only one of them will be perturbed, revealing the signal to be a false alarm.

All that's left when everything else is ruled out would be a passing gravitational wave. When one sweeps through, the mirrors—suspended on strands of glass—twitch in response. That's precisely what happened in the predawn hours on that morning in 2015, first in Louisiana and then, 0.007 of a second later, in Washington. The telltale squiggles in the LIGO data were accompanied by an audio cue, a brief chirp that rose to a middle C, which was calibrated to the frequency of whatever wave came in. It was precisely the fleeting cosmic song the scientists in both LIGO facilities had been waiting to hear.

Ordinarily, even such an unmistakable finding would not mean that gravitational waves had been detected and that Einstein had been vindicated. LIGO is designed with a fail-safe system that occasionally introduces deliberately false readings into the data stream. These so-called blind injections are intended to keep both the computers and the scientists on their toes, checking to see if they can distinguish a real detection from a data glitch. The moment they looked closer at the data, the phony signal would reveal itself for what it was. On that particular morning, however, the decoy system was off-line, meaning that an apparent gravitational wave was, all but certainly, a *real* gravitational wave.

Eliminating the “all but” qualifier would require painstaking checking, a process that took nearly five months before the scientists could go wide with their finding. During that time, the investigators were forbidden to mention a word of what they'd found, even to their spouses and families. In the insular world of cosmological physics, though, there were bound to be whispers—and there were. “All the rumors swirling around out there got it mostly right,” said Reitze at the announcement event, happily conceding that the secret had leaked at least a little.

The detection not only confirmed that gravitational waves exist but illustrated the kinds of forces at play in their creation. The LIGO scientists concluded that the blast that set the wave in motion was caused by a pair of black holes—one with a mass equivalent to 36 versions of our sun and the other with 29—orbiting each other at close to half the speed of light. When they collided, they fused into a single object with a mass of 62 solar masses. That, of course, is three solar masses short of what 36 plus 29 ought to be. It's that missing mass that became the gravitational radiation, releasing—fleetingly—energy 50 times as great as the combined light emitted by all of the stars in the universe. Thorne described it as the most powerful explosion human beings have ever detected,

with the exception of the residue of the Big Bang itself.

None of this puts gravitational waves entirely to bed. LIGO continues to operate, in search of more spacetime disturbances of different intensity and duration. “We are fairly certain that we will find more and more signals,” says Szabolcs Márka, an astrophysicist from Columbia University who works with LIGO. That’s especially likely since other, similar detectors are being planned in Italy and Japan, with the Italian system set to go live as early as 2016. All of the findings will have to be more fully integrated into the theory of general relativity—Einstein’s overall take on gravity—as well as into the subatomic world of quantum mechanics.

Such a push-pull between the vast and the tiny is in some ways a parallel of the LIGO project itself. A billion-year-old blast that literally shook the cosmos produced a minuscule earthly tremor that lasted less than a second. But for that fleeting instant, the universe opened its doors to us.

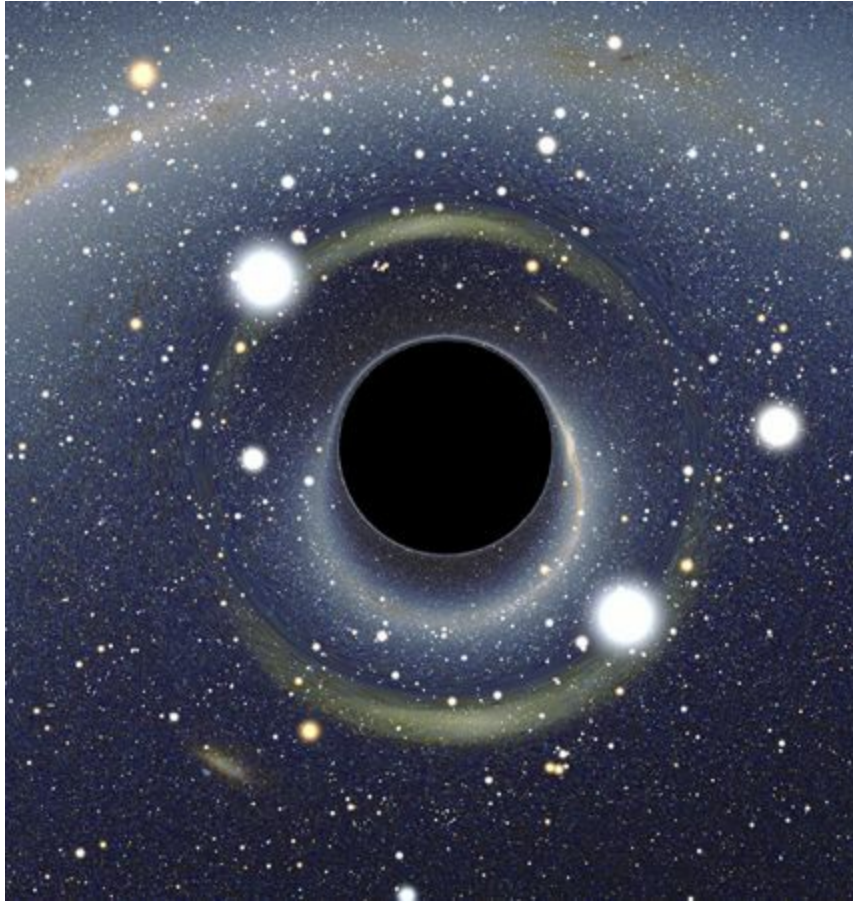


The LIGO in Livingston, La., occupies a remote spot, isolated from noise. Its twin arms stretch 2.5 miles in an L-shaped configuration, waiting for ripples smaller than a proton.



Laser light bounces along LIGO's arms, reflecting off mirrors suspended by strands of glass. Gravitational waves will throw the **lasers out of sync. Technicians must remove all stray dust before sealing the arms and pumping them down to a vacuum.**

New Ways to See Black Holes



In a world of conspiracy theories, it's no wonder that black holes have been called a hoax. They're mysterious and powerful, but—oops!—they're invisible, thanks to gravity so powerful not even light can escape. Three new developments, however, may make it easier to see what goes on in a black hole's vicinity.

A team led by Stephen Hawking has found that as light waves approach the edge of a black hole, they strain to break away from it, forming a bristle of energy that radiates out. When matter falls in, it produces a back-and-forth oscillation in the rays in a pattern unique to the thing that has fallen in. If you know how to read it, you can determine what the lost object was.

Researchers at MIT have developed a way to pool data from radio telescopes around the world to produce an image of the event horizon around a black hole—the circular boundary between the visible and invisible. In a third finding, an international team has observed cold gas falling toward a black hole at high speeds, a departure from earlier theories that suggested a more orderly flow and one made mostly of hot gas. None of this makes black holes easier to see, but it all makes them at least a little easier to understand.

ONCE SOMETHING DOES GET SWALLOWED BY A BLACK HOLE, ALL
INFORMATION ABOUT WHAT IT WAS GETS FOREVER ANNIHILATED
WITHOUT A TRACE

Potential Earth-like Planet Discovered One Star Away

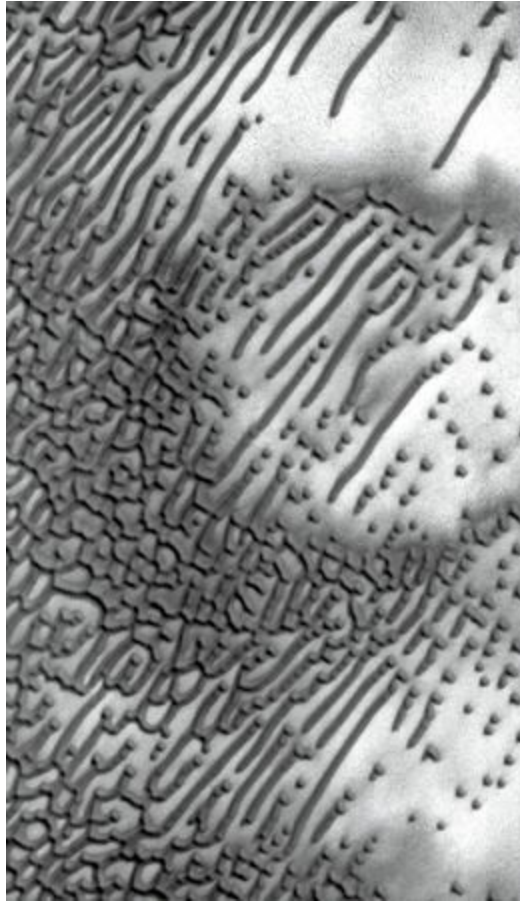


Scientists have discovered a planet in the star system next door that may have certain similarities to Earth. The planet orbits the star Proxima Centauri. While it is much closer to the star (5 million miles away) than Earth is to its sun (93 million miles away), Proxima Centauri is a red dwarf, much smaller and dimmer than our sun. That puts the planet, Proxima b, in the the so-called Goldilocks zone: the not-too-hot, not-too-cold region where water can exist in liquid form. Where there is water, there can, in theory, be life.

What's more, the star system's proximity to our solar system means it could be studied by scientists in the reasonably near future: the planet is 4.2 light-years away, and while it can't be seen with current telescopes (scientists discovered it by looking at gravitational wobbles in its parent star caused by the planet's orbit), future generations of the technology may be capable of sighting it. Robotic probes could also be dispatched to research the planet.

Proxima b is estimated to be at least 1.3 times the size of Earth, though possibly much bigger. It orbits its star in just 11.2 days, and it may be what is known as tidally locked, which means one side is perpetually in light and the other perpetually in darkness.

Signs of Morse Code on Mars



At last, the evidence is in, and no one can deny it any longer: there is intelligent life on Mars, and it's sending us a message in Morse code. That was the chatter, anyway, when an image captured by the Mars Reconnaissance Orbiter revealed what appeared to be a series of dots and dashes on the Martian surface. Alas, it was nothing of the kind.

The entire series of markings sits inside a circular impression that is likely an ancient impact crater, located below the Martian north pole. The walls of the crater scramble the flow of incoming wind, causing it to blow from two directions at once and creating a sculpting effect that forms the long markings in the soil. The short ones, resembling the dots, are formed when the wind, blowing randomly, briefly pulls up sand and stops.

The walls of the crater also prevent more sand from the outside from blowing in and filling the markings as soon as they're created. That means that while later winds will slowly erase the current marks, more will probably be formed in the future. If there is an intelligent mind involved in any of this, it doesn't belong to Martians but to hopeful Earthlings, looking for signs of life elsewhere. We may well find some cosmic company one day, but that day is not today.

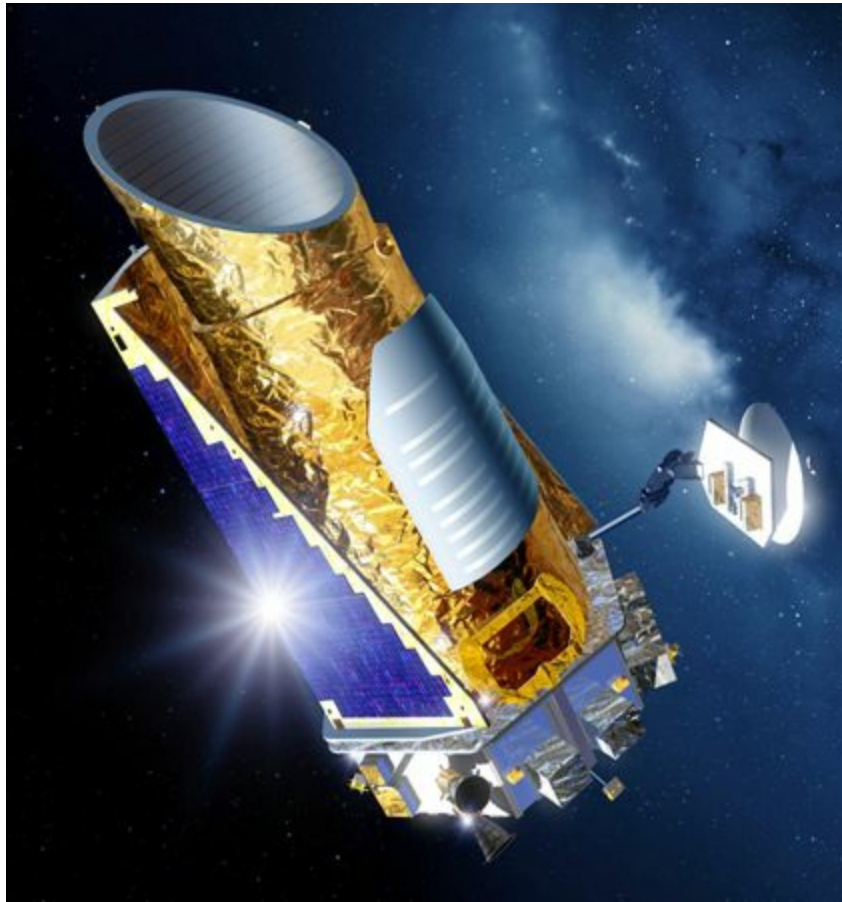
Dramatic Auroras Light Up Jupiter's Poles



The aurora borealis on Earth is breathtaking, but the auroras in Jupiter's atmosphere are a whole other story. Not only do they cover areas larger than the entire Earth's surface, but they are hundreds of times more energetic, and while Earth's auroras are intermittent, Jupiter's keep its poles lit up nonstop. Like Earth's auroras, Jupiter's are created by charged particles in the solar wind, but they're supplemented by more energy streaming from the planet's moon Io.

The Hubble Space Telescope has been studying Jupiter's auroras in conjunction with NASA's Juno spacecraft, which arrived at the planet and went into orbit in the summer of 2016. Hubble captured a series of images of the aurora in ultraviolet, the wavelength of light in which it emits most brightly, represented here in a luminous blue.

New Discoveries Increase the Odds There's Life in Space



Planet hunting is not a growth industry in our solar system. The last time we spotted a new world orbiting our sun was in 1930, when Pluto was discovered. In 2006 the planet was busted down to a mere dwarf planet. Elsewhere in the galaxy, though, things are different, a fact made vividly clear recently when NASA announced that the Kepler Space Telescope had discovered 1,284 new exoplanets, or worlds orbiting other stars. That boosts the total of confirmed or candidate exoplanets to more than 4,700.

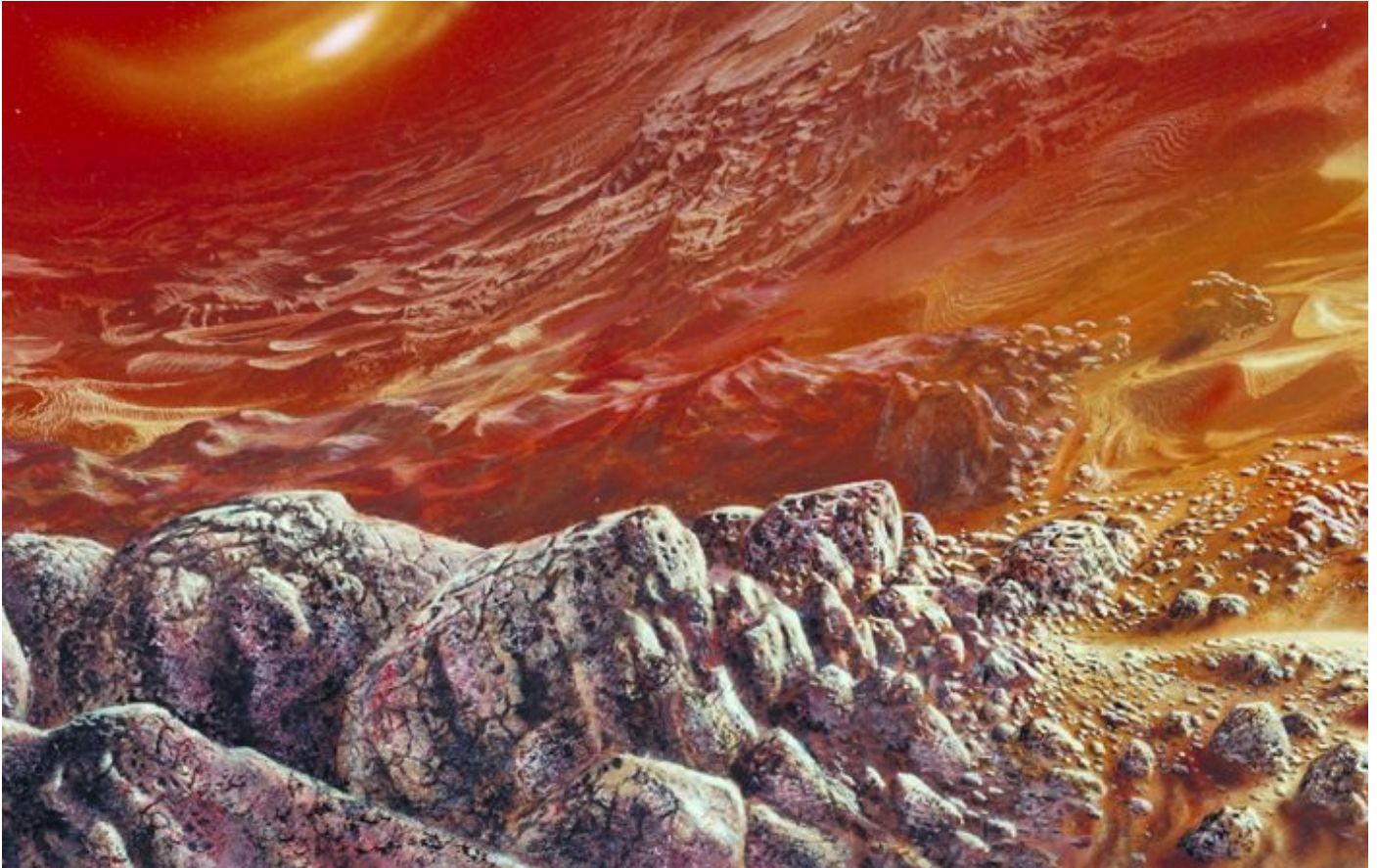
Kepler does its work by staring unblinkingly at a small patch of sky containing up to 150,000 stars and looking for the faint dimming in light when a planet orbits in front of any of them. That method, however, can yield false positives, so investigators developed a computer algorithm that accurately determines the share of candidate planets that can be ruled out. The formula, applied to the thousands of unconfirmed planets in Kepler's data streams, yielded the 1,284 figure. More tantalizing: nine of those new planets are Earth-like in size, making them the likeliest of the bunch to be home to life.

The Hubble Captures a New Image of a Very Old Galaxy



All astronomical images are essentially a look into the past, since it takes time for light to travel to us. This picture, taken by the Hubble Space Telescope, shows the galaxy cluster Abell S1063 as it was 4 billion years ago. What excites astronomers is the opportunity that galaxy gives them to explore a time even earlier. That's made possible by an effect called gravitational lensing, which occurs when a formation like a galaxy magnifies light from objects behind it. Sixteen galaxies have been found this way, including one from just a billion years after the Big Bang. Abell S1063 could reveal even more.

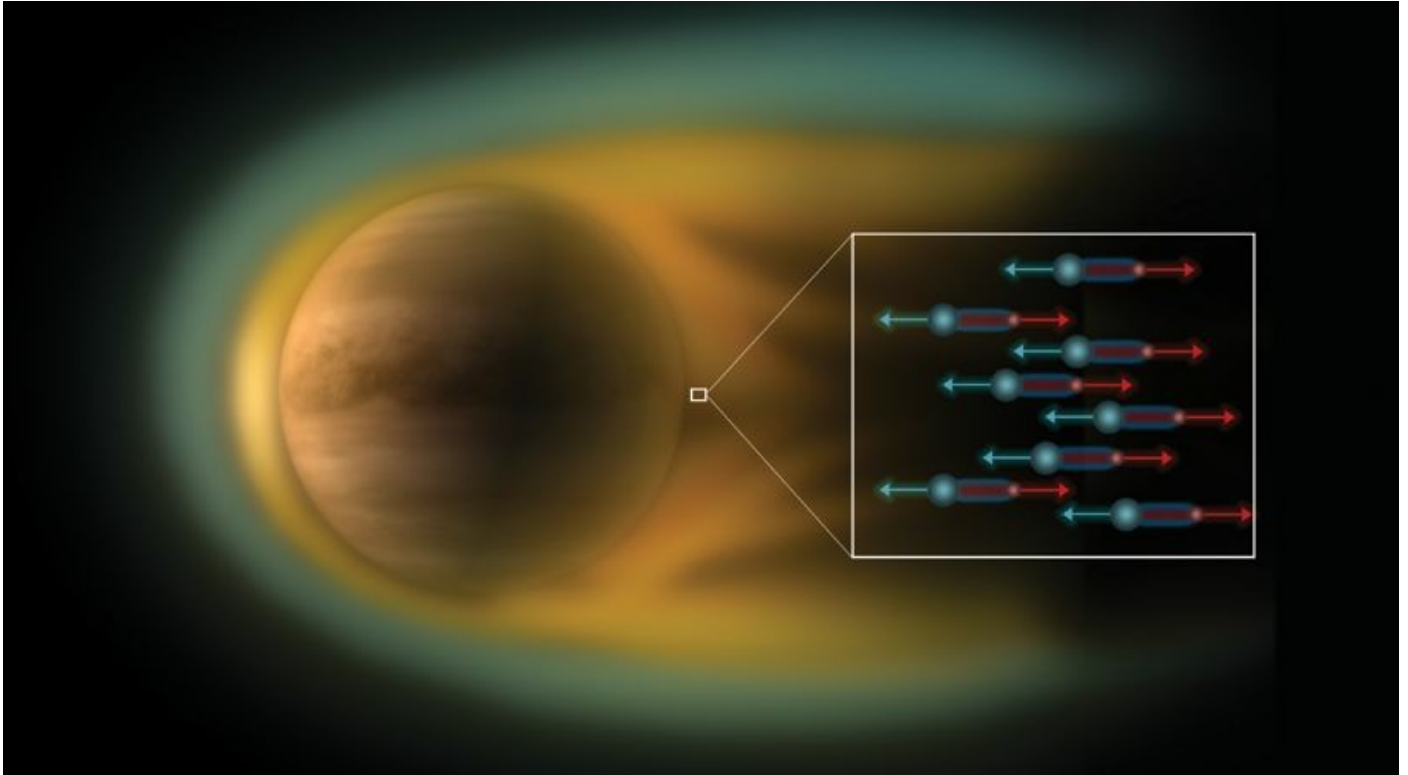
Venus May Once Have Been a Garden Planet



One of the hard facts of our solar system is that even with eight perfectly nice planets, Earth remains the only house on the block with its lights on—at least in terms of life. Now, according to environmental models run by NASA, Venus coulda been a contender. Venus's atmosphere is 90 times as dense as Earth's, which is largely responsible for its nearly 900° surface temperature. The assumption has long been that that's the atmosphere Venus has always had, but atmospheres can change over the eons, and Venus's may have done just that.

Using computer simulations similar to those used by environmental scientists to study global warming, the researchers studied alternative models of an early Venus with a thinner atmosphere; that may have made it possible for liquid water to exist for up to 2 billion years. If so, the good times didn't last. As the sun brightened, the Venusian greenhouse heated up. If Earthlings once had neighbors next door, we did no more.

An Electric Wind May Have Helped Kill Venus



Water molecules fracture at the top of Venus's atmosphere; oxygen (blue) goes one way and hydrogen (red) the other.

The proximity of the Sun and a steadily thickening atmosphere may have been principally responsible for drying out Venus, but even as some scientists have been working to pin the crime on those two perps, other investigators are pointing to a possible co-conspirator: an electric wind.

Investigators at NASA, working with the European Space Agency's Venus Express mission, point to gales of electrical energy that are known to whip through the planet's atmosphere, driven by the proximity of the sun. It's possible that the wind is so powerful it drove water molecules to the upper fringes of the Venusian atmosphere, where sunlight broke them down into oxygen and hydrogen and swept them out into space. That process, NASA said in a statement, could have stripped Venus of the equivalent of an ocean's worth of oxygen and water.

"It's amazing, shocking," said Glyn Collinson, a scientist at NASA's Goddard Space Flight Center. "We never dreamt an electric wind could be so powerful that it can suck oxygen right out of an atmosphere into space. This is something that has to be on the checklist when we go looking for habitable planets around other stars."

HOLY COW!

We're Sending Tiny Probes to Explore Faraway Stars



Laser light fills space sails.

Reaching another star with a spacecraft is a challenge that has always been far out of our technological reach. The closest star to Earth, besides our own, is 4.3 light-years away, and one light-year is nearly 6 trillion miles. But a new theoretical technology involving literally pocket-sized spacecraft and powerful Earth-based lasers could make the journey possible.

The system would entail using light as a sort of wind, with laser pressure directed at Mylar-like sails pushing tiny spacecraft to a fifth of light speed. Getting to the nearest star would still take 20 years, but that's vastly faster than what's possible now. For the time being, the system is just a wild idea, but it's attracting real money: Russian billionaire Yuri Milner has committed \$100 million to the work of a group of scientists who hope to develop a first prototype.

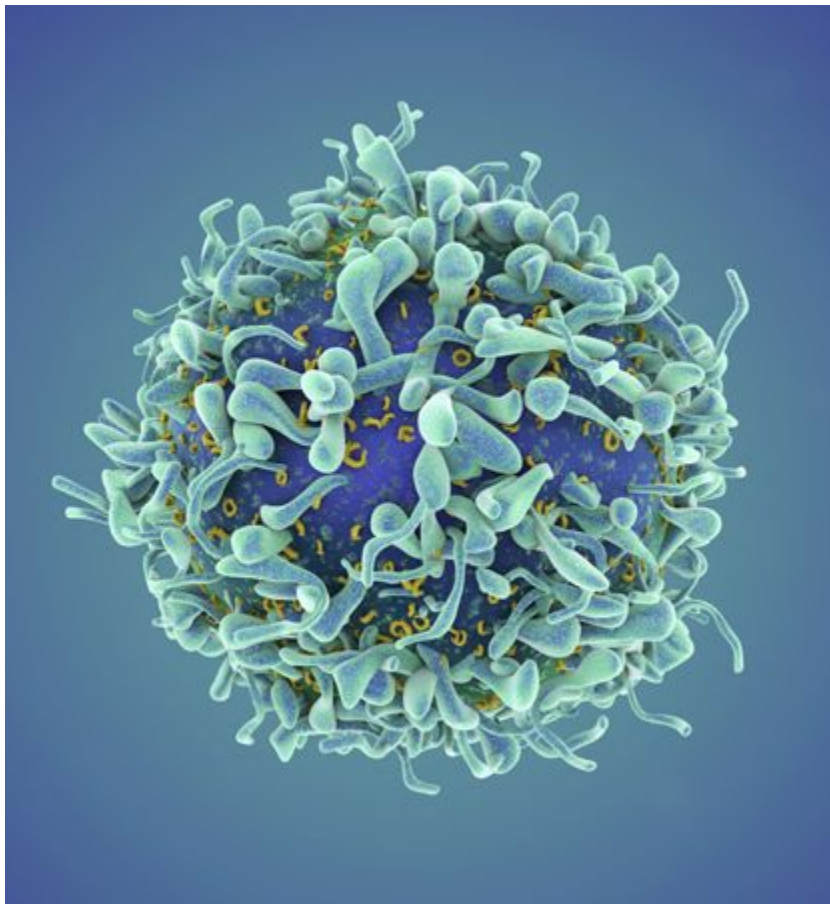
Medicine

Immunotherapy ■ Painkillers and Pot ■ Obesity and Fake Sugar ■ A Promising Alzheimer's Pill
■ Blindness Cured in Mice ■ Cancer and Hot Drinks ■ Game-Changing Prosthetics ■ A New
Antibiotic ■ Exercise and Aging ■ A Penis Transplant

The Cutting Edge of Cancer

Immunotherapy is saving lives in clinical trials. But as these powerful drugs are tested, not everyone gets a shot at a cure

BY ALICE PARK



Immunotherapy uses the body's own natural ability to fight cancer.

Dates are important to a person who knows he's dying of cancer. There's the day when he learned he was sick, and the date of his first surgery. There are also those dates in the future—each one a temporal goalpost that represents hope when every day feels doubtful. For Mike Hindt, who was diagnosed two years ago with metastatic pancreatic cancer, that date was April 23, 2016.

That was when the first of his four children would get married, and despite his dismal prognosis, Hindt, 56, was determined to see his second-oldest say his vows. Mike had run out of traditional treatment options, however. He had already had extensive surgery and been through nearly a dozen sessions of brutal chemotherapy. Since his diagnosis, Mike's wife, Veronica, had made a full-time job of seeking new options for her husband. She ventured into the world of experimental therapies, treatments that haven't been

proved but are promising enough to be tested in people enrolled in clinical trials. Veronica read of an ongoing Duke University trial of a drug called pembrolizumab that is approved and used to treat melanoma and was showing early promise against other types of cancer too. It's the same drug that just a few months later would send former president Jimmy Carter's melanoma, which had spread to his brain, into remission seemingly overnight. In August 2015, Mike learned he'd been accepted into a trial for that same drug.

In principle, immunotherapy is simple. It's a way to trigger the immune system's ability to seek out and destroy invaders. That's how the body fights off bacteria and viruses. But it doesn't do that with cancer, which occurs when cells mutate to outsmart those defenses. That's where immunotherapy comes in. These strategies don't target cancer itself but work on the body's ability to fight it. The therapies, administered in pill or IV form, trigger the immune system to fight cancer cells while keeping healthy cells intact.

In the past decade, scientists have come closer to making a reality of immunotherapy's promise. In studies of people with certain types of B-cell leukemia and lymphoma who haven't responded to any other treatment, upward of 80% of them have seen their cancer disappear. Market experts estimate that in 10 years, immune-based treatments will generate anywhere from \$35 billion to \$70 billion a year in sales. That would make immunotherapy by far the most valuable class of medical drugs in history. There are currently 3,400 immunotherapy trials under way in the U.S. and many more around the world. Immunotherapy, which Vice President Joe Biden said could be "revolutionary," was also central to the Obama administration's "moon shot" to cure cancer.

But it also highlights the chasm between the fast pace of scientific progress and the ability to deliver it to the people who need it most. Scientists are barreling ahead, trying to make some of the most impressive drugs ever developed. Drug companies are bankrolling many of those studies in hopes of bringing to market a revolutionary kind of medicine. And regulatory agencies, focused on safety and effectiveness, push for stringent testing criteria that may shut out many patients from early access to experimental drugs. In the balance are the nearly 7 million people around the world who die of cancer every year. A handful of them may make it into trials and see miraculous results. Others have no choice but to wait.

The question of who gets to try an unproven therapy is particularly loaded because of how good, and how targeted, these new drugs are. Immunotherapy is largely ultra-personalized medicine, and it requires ultra-personalized trials. This makes it nearly impossible for patients to find an appropriate clinical trial, discouraging all but the most stubborn.

There are reasons some doctors are wary of recommending clinical trials, even for treatments as promising as immunotherapy. On a practical level, most do not have the time to keep up with the thousands of studies undertaken by drug companies and the government, so they may not know what to recommend. Many are also unwilling to take on the responsibility of putting their patients on an untested, and costly, treatment.

What many doctors do instead is refer patients to clinicaltrials.gov, a website that lists

every trial of an experimental therapy being tested in the U.S. or one of more than 150 other countries. It provides contact information and details about which patients qualify for the studies, making it the default resource for anyone in that final phase of cancer care. But people who use it complain that it's full of errors, including wrong phone numbers and inexact information about eligibility.

Even if a patient can find the right one, clinical trials are designed to answer scientific questions, not provide an immediate cure. That's why trials have strict and specific criteria: people have to have a certain type of disease, at a certain stage, and show certain symptoms. And with the latest immunotherapy drugs, the eligibility criteria are narrowed even further.

The researchers, the drug companies and the Food and Drug Administration all want to ensure that any changes in patients can be rightly attributed to the drug that is being tested and not to something else the patients took before. Drug companies also have considerable control over whom they admit to their trials—and whom they reject—using those same eligibility criteria. Smaller companies, which have less funding to support large and lengthy trials, may prefer to keep the most responsive patients in their studies so that the results look more favorable and their investment pays off.

Still, even with those patient-unfriendly pressures, Veronica Hindt was certain the trial was her husband's only chance at survival. "Mike felt wonderful on the [pembrolizumab]," she says. "He was doing really well." But six weeks after he was enrolled, Mike was dropped from the trial. Veronica says he hadn't had any bad reactions at the time he was taken off the drug. His doctors say his liver lesions were still growing too fast, beyond what was allowed by the study protocol. That meant, according to Duke and Acerta Pharma, the company sponsoring the study, that he no longer qualified for the trial. "We didn't know you could get booted out of a trial," Veronica says. "We were blindsided."

Since Mike was removed from the trial early, it's impossible to know what would have happened to him. About 30% of people taking this type of immunotherapy end up in remission. That's where the process of clinical trials can backfire for patients who are sick today. The purpose of these studies is to produce the best new therapies—not for patients who have already been diagnosed but for those who are in coming years. This raises a question as important as it is unanswerable: How does one marry patients' hopes of being helped by an unproven drug with the scientific and financial requirements of researchers and drug companies? "It's hard," says Michael Neuss, the chief medical officer at Vanderbilt-Ingram Cancer Center in Nashville, Tenn. "There are competing goals and a lot of tension."

As with any major advance in medicine, the costs will be considerable. At the moment, treating a patient in a clinical trial with immune-based drugs runs about \$200,000 a year. But since leading cancer experts predict that immune-based therapies may eventually replace chemotherapy, this research will likely find the investors it needs.

For Mike Hindt, the results of those trials will come too late. In March 2016, a

hospital in Georgia responded to Veronica's inquiries and offered to give Mike an experimental immunotherapy drug, off label. That would mean he wouldn't be part of a study, and it could also mean he wouldn't be able to join future trials, since many don't allow any previous off-label-drug exposure. Mike and Veronica decided to go for it anyway. "I vowed to my children to leave no stone unturned in Mike's care," Veronica says.

But before they could make the 2½-hour drive from their home in Charlotte, N.C., to the Georgia Cancer Center in Augusta, and before he could give his son a bear hug and welcome his first daughter-in-law to the family, Mike passed away. The official cause of death was metastatic pancreatic cancer.



STEPHANIE FLORENCE, *pictured in March 2016 in her hometown of Lewiston, Idaho, took an immunotherapy-based drug, and her lymphoma went into remission. Diagnosed in 2006, she had been told that her cancer was incurable. To get into a clinical trial, she called the study's lead doctor repeatedly and sometimes showed up for unscheduled visits.*



DORIS ANN PRICE has metastatic breast cancer. She's pictured in March 2016 in New Hampshire. She and her husband relocated from their home in North Carolina to the Boston area, where they are staying with a friend, in order to participate in an immune-based-drug trial. She's responding to the treatment, and her doctor says that if it doesn't control the spread of her cancer enough, she can move on to another study.



VERONICA HINDT speaks of her husband, Mike, pictured in 2010, before he was diagnosed with metastatic pancreatic cancer. He was dropped from an immune-based-drug trial in the summer of 2015.

“We didn’t know you could get booted out of a trial. We were blindsided.”

Legal Marijuana May Reduce Opioid Abuse



In states where medical marijuana is legal, prescriptions for drugs for conditions where pot could serve as an alternative have dropped significantly, according to a recent report published in the journal *Health Affairs*.

One of the most stunning decreases in the report was in prescriptions for painkillers, which are now in the spotlight due to a nationwide epidemic of opioid addiction. The researchers found that doctors in states where marijuana is legal ended up prescribing an average of 1,826 fewer doses of painkillers per year.

To reach these findings, the study authors looked at data on all prescriptions filled by Medicare Part D enrollees from 2010 to 2013. They saw a link between the legalization of medical marijuana and a drop in prescriptions for antidepressants, seizure medication, sleeping pills, anxiety medication and anti-nausea drugs.

So far, 28 states have legalized marijuana for medical or recreational use, though not all of the states have fully implemented those laws.

Currently, marijuana is classified as a Schedule 1 drug by the U.S. government, which implies it has high potential for abuse, though researchers argue that evidence doesn't support that. "Our research suggests that more widespread state approval of medical marijuana could provide modest budgetary relief," the study authors write.

More research is needed to understand the link, but the researchers also argue that their findings suggest that people are truly using marijuana for medical reasons.

Fake Sugars Have Some Bad Health Effects

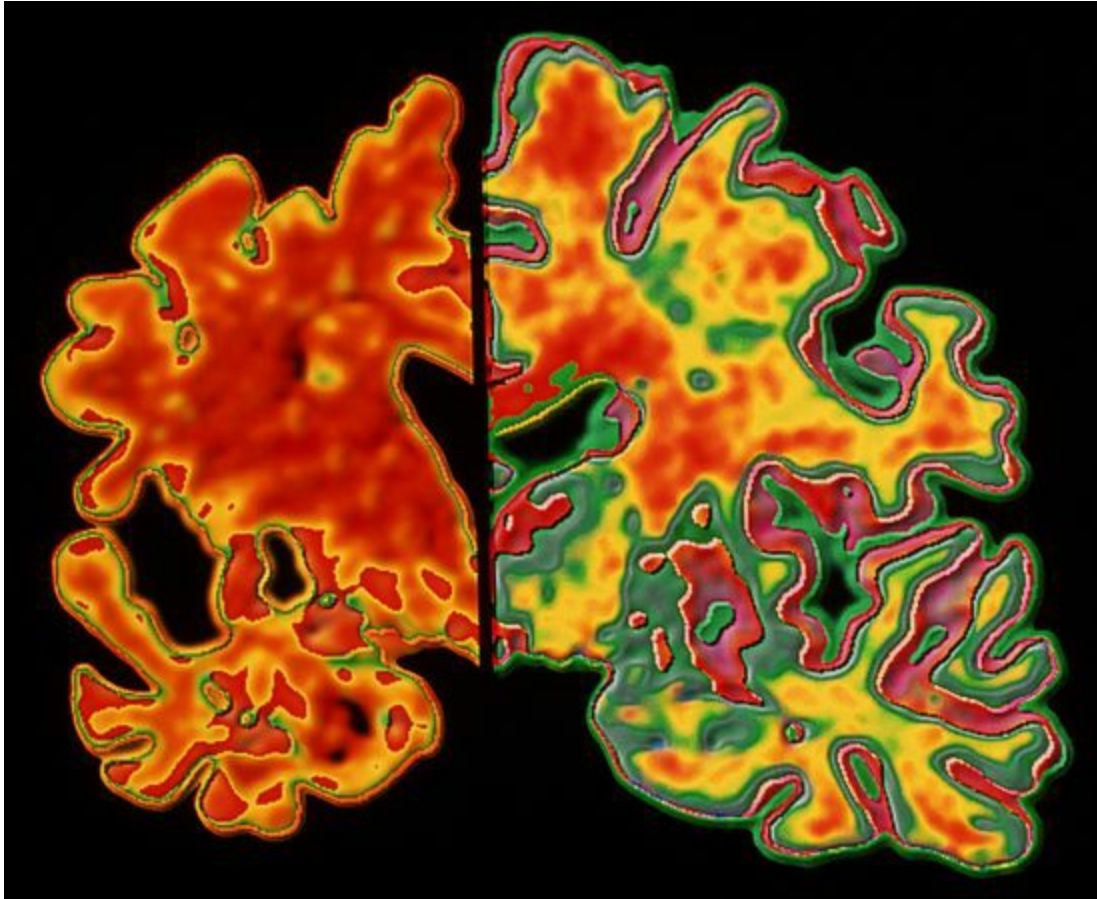


It turns out artificial sweeteners may be too good to be true.

In a report published in *JAMA Pediatrics*, researchers studied more than 3,000 pregnant women and their infants. The women answered questions about what they ate, and their babies were tracked for a year after birth. Moms who reported consuming more artificial sweeteners—such as Equal (aspartame), Splenda (sucralose) and Sweet’n Low (saccharin)—in beverages were twice as likely to have babies who were overweight or obese at one year, compared with women who reported using artificial sweeteners less.

This finding does not indicate that artificial sweeteners cause obesity in kids, but it adds to prior research that found similar links between sugar substitutes and health issues, including weight gain, in animal and human studies. This may be the first human study, however, to suggest that artificial sweeteners during pregnancy might affect weight in infants.

A New Alzheimer's Drug Shows Promise



The drug may break down protein amyloid buildup in the brain.

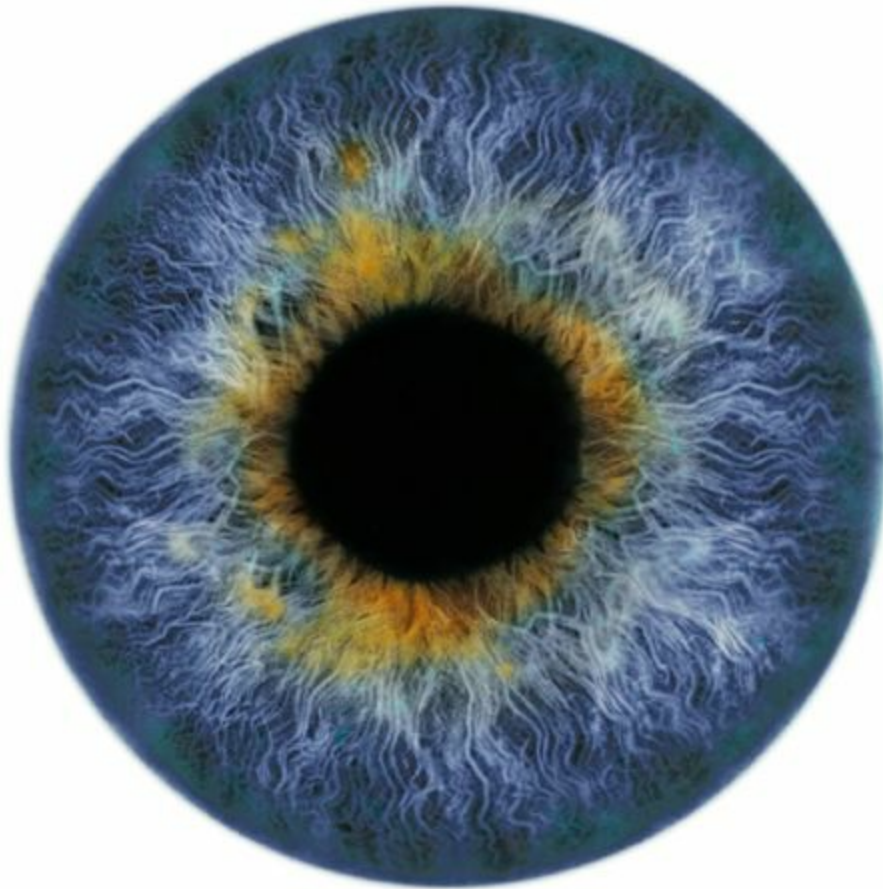
Treating Alzheimer's disease may not ever be simple, but in a paper published in the journal *Nature*, scientists from a biotech company report the most encouraging results so far for one drug that could play a key role.

Researchers at Biogen, based in Cambridge, Mass., say that the antibody they have been testing can bind to and break down the amyloid protein that builds up in abnormal amounts in the brains of Alzheimer's patients. Even more encouraging, they report that for a small number of people in the study, that reduction in amyloid plaques was linked to a slowing in the cognitive decline associated with Alzheimer's. "We are pretty certain of the fact that the antibody reduces the amyloid plaques and in some ways gets rid of the majority of it," says Alfred Sandrock, the senior author of the paper.

In the trial of 165 people with mild to moderate Alzheimer's, participants were randomly assigned to receive either a placebo or one of three different doses of the drug. After a year of monthly infusions, those receiving the highest doses showed the most reduction in amyloid compared with data from the start of the study.

The small number of people who were tested on cognitive function showed promising signs that reducing the amount of amyloid in the brain may translate into improved function, but that's just an early hint. The company is recruiting people for two other ongoing trials that aim to answer that question.

Blindness Is Cured in Mice, in a Breakthrough Study



For the first time in history, a group of scientists in the U.S. helped mice with destroyed optic nerves to see again.

For the study, published in the journal *Nature Neuroscience*, researchers at Stanford University crushed the optic nerve in one eye of mice to learn how vision nerves grow. Once the nerves were destroyed, long extensions—which were sent out by nerve cells from the eye to the brain—started to shrivel, eventually severing any connection to the brain and resulting in blindness. But the researchers found that a combination of visual stimulation of the nerve, along with nerve-growing chemicals, could rescue these extensions, called axons, and coax them into stretching out again. The axons were able to find their appropriate connections to the correct sight-dedicated parts of the brain. The result? Restored vision in the lab mice.

A few weeks later, the researchers saw evidence of axons extending back into the brain from the eye. The combination of keeping the damaged but remaining axons stimulated, by exposing the mice to bars on a screen that were moving in different directions, and the nerve-growth factors led to a 500-fold increase in axon regrowth. It's still early, but the researchers say they hope their work will one day help people with blindness.

Very Hot Drinks Are Named a Probable Carcinogen by Health Experts



In 2016, the World Health Organization announced that after thorough investigation into existing research, it had determined that hot drinks such as coffee, tea and maté may increase a person's risk of cancer. WHO's International Agency for Research on Cancer reviewed around 1,000 studies on high-temperature beverages and their potential link to cancer. The group concluded that drinking very hot beverages, defined as anything above 149°F—cooler than a cup of coffee from most takeout spots—is linked to a higher risk of cancer of the esophagus.

The link remained strong even after the scientists adjusted for other factors, like smoking and other unhealthy behaviors. Because the heat affects delicate tissues in the esophagus, the resulting damage may trigger more rapid turnover of the cells, which can lead to out-of-control, malignant growth.

Technology Helps a Quadriplegic Man Move His Hands



A quadriplegic man was able to move his hand simply by willing it to happen with his mind—a medical breakthrough made possible with the help of a new device still in its testing phase.

Ian Burkhardt, 23, who was paralyzed in a diving accident four years ago, was the first person to try out a decade-in-the-making technology called Neurobridge, which sends neural signals directly to muscles.

In April 2016, researchers planted a tiny chip that interprets brain signals into the part of Burkhardt's brain that controls hand and arm movements. The chip interprets signals from a computer and transfers them to a sleeve that stimulated Burkhardt's muscles, thereby skipping over his damaged spinal cord.

An Antibiotic Discovery in Human Noses



A new antibiotic is found in the human nose.

German researchers have found a bacteria that produces an antibiotic able to combat the often-resistant pathogen *Staphylococcus aureus*, and it's in the human nose. The antibacterial substance, which researchers named lugdunin, was able to effectively treat infections in mice caused by *S. aureus*, which can cause severe skin and wound infections, according to a study published in *Nature*. When scientists applied the antibiotic to skin lesions of infected mice, they observed “dramatic reductions” in the wounds.

Such infections have become increasingly resistant to the antibiotics commonly used to treat them, including methicillin, leading to the “super bug” MRSA, or methicillin-resistant *S. aureus*. Scientists have said, though, that lugdunin may be able to combat more antibiotic-resistant strains and may not be prone to develop resistance like other antibiotics. Though finding lugdunin is exciting, scientists still aren't sure how it works, and clinical development could be years away.

Exercise Can Slow Brain Aging by 10 Years



We know that exercise is good for the body and the brain. But actually being physically active, at least on a regular basis, isn't always easy. For days when you just don't want to break a sweat, there's new motivation in the form of scientific evidence: physical activity can slow brain aging by as much as 10 years, reports a study published in the journal *Neurology*.

It's among the first studies to put a number on how beneficial exercise can be for the brain. The researchers asked a group of 876 men and women of diverse racial and ethnic backgrounds about their exercise habits. The subjects also answered questions that tested their cognitive abilities, including their memory, organization, reasoning and thinking speed. Five years later, about half of the study group performed the same tests.

People who reported doing more physical activity showed higher scores on cognitive tests—consistent with previous studies linking more exercise to better brain health. But when the researchers adjusted for the effect that factors like high blood pressure, diabetes and heart disease can have on brain function, the link disappeared. Conditions like these may impair blood flow to the brain and therefore compromise cognitive functions.

The researchers then focused on people in the study without these risk factors. They found that people who exercise more had higher cognitive scores, while those who were less physically active tended to have lower scores. This trend remained strong in two areas in particular: thinking speed and memory of specific past events. They also found that people who exercised less showed sharper declines in their cognitive scores than

people who were more active. The drops were equivalent to the declines found during normal aging over about 10 years, they concluded.

HOLY COW!

Doctors Perform First Penis Transplant in the U.S.



Thomas Manning, at right

The first penis transplant operation in the U.S. was performed at Massachusetts General Hospital in May 2016. The recipient, Thomas Manning, 64, had his penis replaced due to a rare cancer. He had persistently asked his surgeons about the possibility of a transplant, and finally, he got his wish.

The procedure—which required seven surgeons, six residents and more than 30 other staff members—took 15 hours and involved connecting the arteries, veins, nerves, urethra and flesh of a deceased man’s penis to Manning’s groin. After the surgery, doctors said they expected that sexual function would return within a few months.

For the rest of his life, Manning will take daily drugs that suppress his immune system so his body won’t reject the new penis. Doctors hope to also offer the procedure to veterans who have suffered wartime injuries. Penis transplants are estimated to cost from \$50,000 to \$75,000.

Chemistry

The Magic of CRISPR ■ A New Way to Fight Climate Change ■ The Surprising Threat from Sunscreen ■ Frozen Coffee ■ Restricting Pesticides ■ Teflon Blues ■ How Plants Clean the Air ■ Regulating Chemicals ■ The Persistence of BPA ■ Olympic Blues

Life, the Remix

A new technique that lets scientists edit DNA with ease is transforming science—and raising difficult questions

BY ALICE PARK



Kathy Niakan's laboratory at London's Francis Crick Institute is the size of a walk-in closet, but between its walls she's working on one of the most expansive frontiers ever contemplated by science.

Sometime soon, Niakan will place a human embryo on the platform of her microscope. With one hand, she will steady the embryo—an egg that has been fertilized by a sperm but hasn't yet begun the cell division that eventually results in a person. With the other, she will maneuver a tiny pipette up against the embryo and inject a specially prepared liquid. If all goes as expected, the liquid will alter the DNA at the core of the cell—literally rewriting the embryo's genetic code. At that point, Niakan will have effectively edited this potential human being. She isn't interested in creating designer humans; instead, she's trying to learn how healthy humans are made, by identifying which DNA sequences are crucial to helping a human embryo develop normally.

This research would be significant enough all on its own. Niakan, a Ph.D. from UCLA, is trying to override nature's selections, instead generating an outcome that she has designed. But what's truly remarkable is that her work represents just one front of a broad revolution in genetics sparked by the technique called CRISPR-Cas9. Just four years old, this discovery is transforming research into how to treat disease, what we eat and how we'll generate electricity, fuel our cars and even save endangered species. Experts believe that CRISPR can be used to reprogram the cells not just in humans but also in plants, insects—practically any piece of DNA on the planet.

So while Niakan moves forward with her work, scientists around the world are exploring other ways to deploy this powerful new tool. At the University of California, Riverside, a team is reprogramming a yeast strain to convert sugars into the components of biofuels. A plant pathologist at Pennsylvania State University has created a mushroom that doesn't brown. At Temple University in Philadelphia, scientists have used CRISPR to successfully excise HIV from human cells in a lab—and in living animals infected with the virus. Scientists envision creating cows that make more milk, tomatoes that don't taste like water and—that stuff of science fiction—the ability to bring back extinct species. In July, the National Institutes of Health (NIH) will issue recommendations on the first bid to test a CRISPR-based medical treatment, on people with myeloma, by taking out their blood cells and revving up their cancer-fighting genes with CRISPR and then returning the newly edited disease-free cells. "It's a game changer," says David Baltimore, a Nobel laureate for his discoveries in viral cancer genetics.

The potential is enormous, but to many, the risks are equally great. Even well-intentioned scientists don't understand all the possible downstream effects of unleashing altered organisms into the wild—including the human gene pool. The simplicity that makes CRISPR so powerful raises the possibility that terrorists or rogue states could deploy it as a weapon—a fear that led director of national intelligence James Clapper to include gene-editing methods like CRISPR on a list of mass-destruction threats earlier this year. But no matter the dangers, rewards or questions, this technology is being used now. Will scientists know what to do with it? "Right now the only limiting factor in CRISPR is our imagination," says Rodolphe Barrangou, a CRISPR expert at North Carolina State University. "The question now is, Where can you not use it?"

An equally important question might be, Where *should* you not use it? CRISPR research keeps accelerating and not just because of the excitement of scientific discovery. The biotech industry is poised for huge profits as everything from CRISPR disease treatments to CRISPR pigs and even mushrooms comes to market. The speed with which CRISPR has infiltrated so many areas of science is sobering to those most familiar with what the technology can do. "I worry a lot," says George Church, a geneticist at Harvard University. "And I have every reason to encourage citizens at large to worry as well."

So, apparently, does the national-security establishment. CRISPR means that most microbes driving infectious diseases are just a few DNA edits away from becoming superstrains that could wipe out unprepared populations. That's the thinking that

prompted Clapper to classify CRISPR as a weapon of mass destruction. With the tools easily bought online, it would be theoretically possible to engineer a killer mosquito that transmits a deadly disease, or a DNA-damaging virus, that could infect human cells and decimate the population.

While Niakan plans to use CRISPR on human embryos, she will not allow them to develop beyond seven days—or about when they’ve divided enough times to have 200 to 300 cells. (U.K. law prohibits letting human embryos in research to progress past 14 days.) But with research and commercialization evolving so quickly, it isn’t hard to imagine some next steps—including some with decidedly eugenic overtones. If IVF clinics gain the ability to edit out severe genetic diseases, will some move on to creating babies tailored to parents’ preferences for height or intelligence or athletic ability?

Are there constructive ways of developing appropriate limits and guidelines? The leaders in the field have triggered an ongoing discussion in the scientific community. For now, the National Academy of Sciences has called for researchers to voluntarily refrain from using CRISPR on human embryos that are meant to come to term, calling such studies “irresponsible” at this point. Such guidelines, while not binding in any legal or regulatory way, can still provide a crucial framework for shaping the way powerful technologies like CRISPR are used. That’s especially true in the U.S., where studies not funded by the government are not bound by any federal laws overseeing human-embryo research.

The reason for the permissive legal environment in the U.S. has a lot to do with politics. Nearly every previous attempt to regulate embryo experiments was swept quickly into a polarizing debate over abortion and failed to address scientific questions about the potential value of the research. “We are probably behind the eight ball on addressing the questions that gene editing raises from an ethical standpoint,” says Ezekiel Emanuel, the chair of medical ethics and health policy at the University of Pennsylvania School of Medicine.

For now, the only agreement among experts is that using CRISPR to treat humans—including editing the genomes of eggs, sperm or embryos that are allowed to develop into human beings—is premature.

In her Crick Institute lab, Niakan is well aware of the precedent that her work will set for how CRISPR will be used in human embryos for years to come. She points to two cabinets devoted to the paperwork for tracking every embryo that she receives and its journey through the other embryo research she does in her lab. “We are inspected on a constant basis,” says Niakan, referring to the U.K. regulators. “They want to make sure the embryos are being used for this specific research project and that they are traceable from the time they enter our facility to the time they are used in the project. They also check that the people who donate them are given the proper informed consent about the research.”

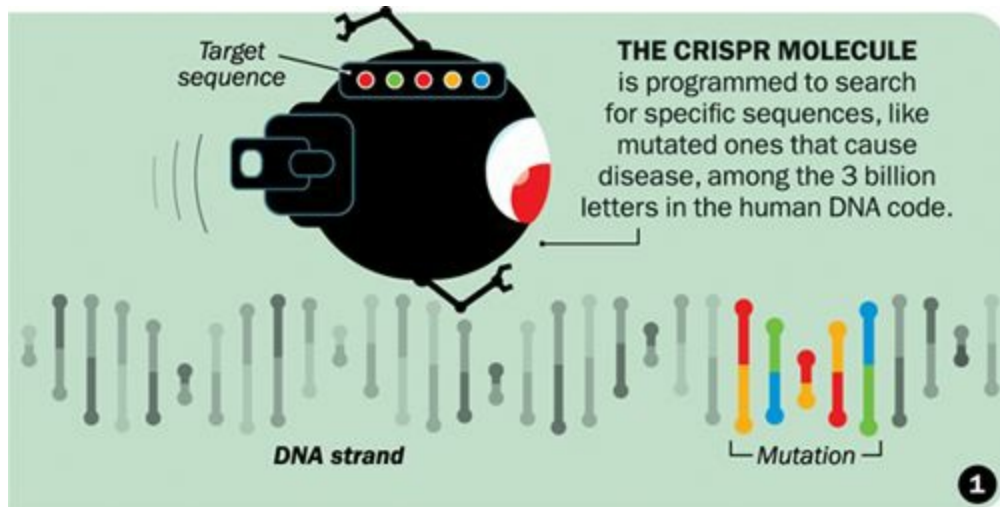
So she is proceeding—carefully—with that first sanctioned edit of a normal human embryo, hoping to learn about the earliest steps in human development. By selectively snipping out genes that previous research suggests might be important in helping early

embryos thrive, she can come up with a list of genes that all healthy embryos need. When she splices out each gene in question, the DNA will attempt to repair itself. She knows the repairs will likely fail since the disruption is so dramatic. The gene will no longer be able to make whatever contribution it has to the embryo's development, setting off a chain reaction that will prevent the embryo from developing further. But from that failure new knowledge will be acquired—knowledge that would be “technically virtually impossible” to get without CRISPR. What she learns could help prevent miscarriages and help more couples struggling with infertility to start families.

That's what keeps Niakan focused on completing her CRISPR experiments—and intent on including the public in the conversation. “I think it's important to be transparent and to be open about why we are picking certain genes and why we are doing this study. Most scientists don't do that. But in this case, I want them and the public to appreciate the logic of what I'm doing,” Niakan says. “I hope everybody working on CRISPR now and in the future will be that transparent.”

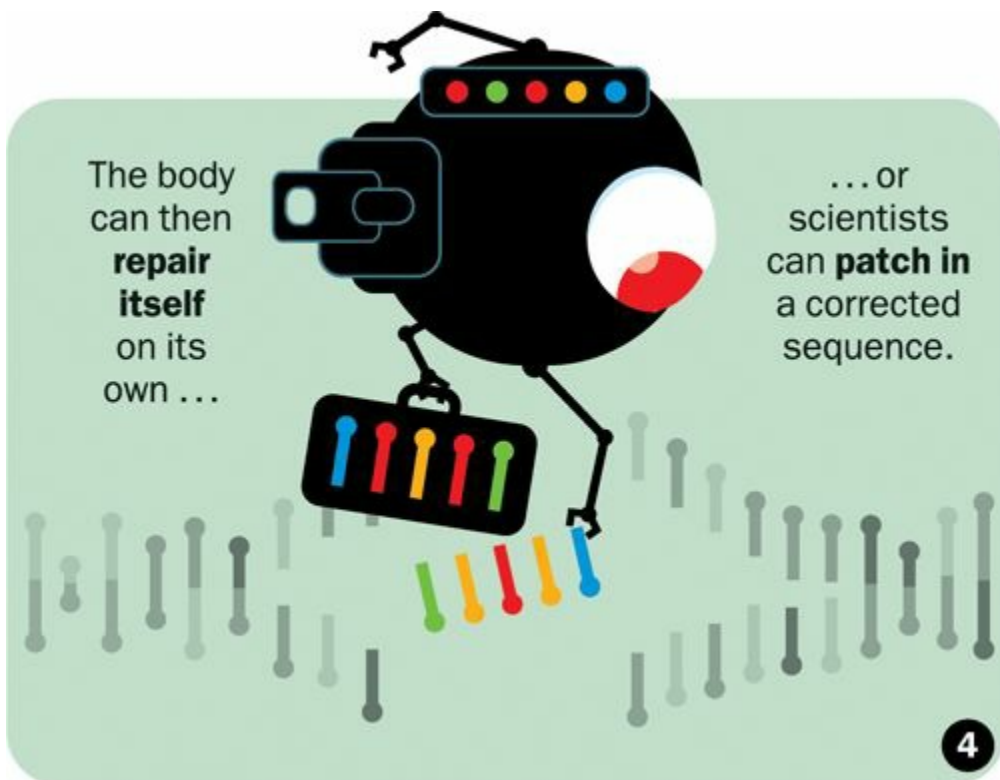
HOW CRISPR EDITS DNA

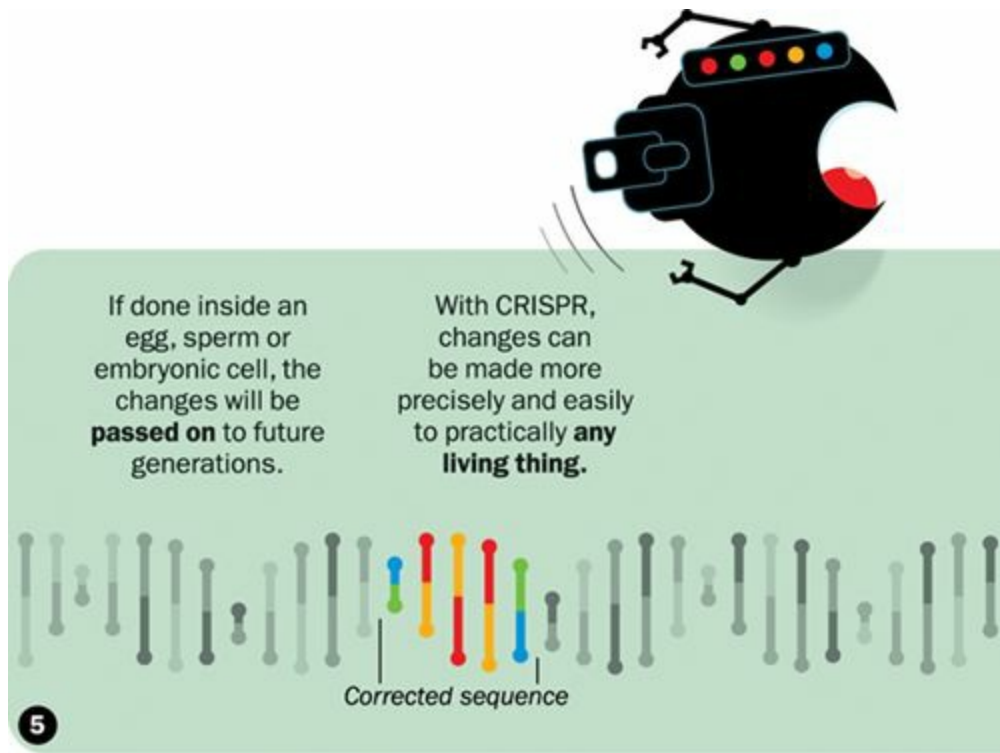
Every cell in the body carries a copy of genetic code—a blueprint for who we are. CRISPR allows scientists to edit that code with more control than ever before



Once the mutation is found, CRISPR **unzips** the twisted DNA strands...







“Right now the only limiting factor with CRISPR is our imagination. The question now is, Where can you not use it?”

—RODOLPHE BARRANGOU, *a food science professor at North Carolina State University and a pioneer in the use of CRISPR technology*

How Sunscreen Chemicals Are Destroying Coral Reefs



A chemical in sunscreen may be contributing to the destruction of coral reefs as swimmers trying to protect their skin venture near reefs. Researchers found that the chemical oxybenzone has toxic effects on young coral that cause endocrine disruption, DNA damage and death of coral, among other problems. Oxybenzone also exacerbates coral bleaching, a process by which coral reject symbiotic organisms and lose their color. Bleaching has been particularly prevalent in recent years due to rising sea temperatures.

Between 4,000 and 6,000 tons of sunscreen enter coral reef areas around the world each year. That's a lot of sunscreen, considering how little it takes to cause toxic effects. According to the new research, toxicity occurs at a concentration of 62 parts per trillion. That's the equivalent of a drop of water in an Olympic swimming pool.

Sunscreen is part of a long list of threats to coral reefs that includes pollution and overfishing. One estimate from the National Oceanic and Atmospheric Administration put the economic contribution of coral reefs around the world at \$30 billion each year.

Stemming HFC Emissions



Climate negotiators agreed on Oct. 15, 2016, to phase out the pollutants known as hydrofluorocarbons (HFCs). The deal represents crucial progress toward meeting the goal of 2015's landmark Paris Agreement, which set out international targets in order to reduce the rate of increase in global temperatures.

HFCs, introduced widely in the 1990s to replace ozone-depleting gases, can be found in household goods such as air conditioners and refrigerators. They are thousands of times as destructive to the climate as carbon dioxide, when compared pound for pound. Scientists had warned that HFC use would expand significantly in the coming decades as incomes rise in the developing world.

Scientists say the deal could reduce warming by as much as 1°F by 2100, and the accord was just the latest breakthrough in climate diplomacy. The Paris Agreement was swiftly ratified, and negotiators also agreed in October to cut aviation emissions. Together, the accords show a new urgency to act on climate change.

A GROUP OF **100** COUNTRIES HAS CALLED FOR GROWTH IN THE
USE OF HFCS TO PEAK BY 2021

Science Figured Out How to Make Coffee Even Better



As it turns out, making a great cup of coffee is not so much about what you put into it once it's brewed—it actually depends on what you do to the beans beforehand. A 2016 study found that chilling coffee beans creates a better flavor for the brew, meaning your freezer could be the secret to a better tasting cup of joe.

University of Bath scientists conducted an experiment with the U.K.-based coffee shop Colonna & Small's in order to optimize coffee flavor. They discovered that the key is particle distribution. The researchers concluded that “grinding colder coffee beans produces a more uniform particle distribution, with a decreased particle size.”

The end result is flavor: “Cooling of coffee beans significantly decreases the rate of mass loss through volatile sublimation/evaporation,” the team found. “Coffee that is ground and brewed cold could potentially demonstrate increased aroma and/or flavor in the eventual brewed cup.”

The colder the better: Researchers tested temperatures as low as -321°F , and “the colder the beans, the finer and more uniform the particles were from the grind,” Phys.org reported.

The researchers speculate that their discovery could be adopted in coffee chains worldwide. “It could have a major impact for the industry,” said Christopher Hendon, who was a chemistry Ph.D. student at the University of Bath at the time of the study. “People are trying to produce a very high-quality drink with really quite powerful tools

and are willing to try new things.”

How Activists Are Restricting Use of a Major Pesticide



Glyphosate, the world's most widely used herbicide, has become a target for environmentalists. But despite growing evidence of the chemical's potentially dangerous health effects—it was deemed a “probable human carcinogen” by the World Health Organization last year—efforts to ban it in the U.S. have failed.

But on the Hawaiian island of Maui, nearly 5,000 miles from the offices of federal regulators in Washington, D.C., a small group of activists have figured out how to use a little-known provision of a federal law to stop some uses of glyphosate in their community. Federal laws require pesticide sprayers to follow the safety instructions on a product down to the letter. And because those safety instructions can be difficult to meet with glyphosate—requiring that the pesticide dry before people are allowed to pass through a sprayed area—its use is all but impossible.

“Most people are unaware that that’s a requirement of the label. They just spray it and think it’s safe,” says Brad Edwards, a social worker turned anti-pesticide campaigner in Hawaii. “This now means that government, individuals, condo associations—they need to take measures to keep people and pets off sprayed areas until they dry.”

People Are Still Exposed to Teflon at High Rates



Scientists now know that teflon contains a consumer chemical called PFOA that is linked to birth defects, heart disease and other health issues. It now turns out that PFOA is dangerous at concentrations far lower than previously recognized, according to a 2016 investigation.

The investigation, conducted by the Environmental Working Group (EWG), found that exposure to PFOA is harmful at levels far lower than previously recognized by the Environmental Protection Agency. Tests found PFOA at unsafe concentrations in 27 states, affecting more than 6 million people.

“It appears even the smallest levels we’re able to measure have harmful health effects,” says Bill Walker, author of the EWG report on the investigation.

The EWG also called on manufacturers to stop using chemicals in the same family as PFOA and PFOS, known as PFCs. Though different in structure, these chemicals serve the same function in consumer products, the organization said, and preliminary research has shown that they likely also have the same detrimental effects on the human body.

In the U.S., chemicals have historically been under-regulated. Manufacturers can use them until problems arise rather than prove they are safe. Meanwhile, some chemicals, like BPA, have been replaced due to negative health effects only for researchers to discover that substitute chemicals cause the same problems. Legislation to change the approach to chemical regulation is stalled in Congress.

Simple Houseplants Can Clean the Air



The crassula plant will help keep your air clean.

Indoor air pollution is a common and important threat to human health, according to researchers led by Vadoud Niri of the State University of New York, Oswego, and can even lead to symptoms of “sick-building syndrome,” such as headache and fatigue. Volatile organic compounds (VOCs), which are emitted as gases from cigarette smoke, paints, furniture, copiers and printers, cleaning supplies, and dry-cleaned clothes, are often to blame.

Installing ventilation systems or other high-tech solutions can help remove VOCs from indoor environments—but they can be expensive. So Niri turned to plants, which take in CO₂ through their roots and leaves. Previous research has also shown that greenery can absorb VOCs like benzene, toluene and formaldehyde. While all of the plants they tested reduced some of the air pollution, certain ones—especially the crassula plant and the spider plant—were more helpful than others.

Niri points out that his study was performed in a sealed chamber, not a real-life setting. The next step in his research is to test these plants’ abilities in an ordinary room. Niri also says that while plants may significantly improve air quality in polluted indoor areas, it’s still better to eliminate the source of these harmful chemicals. Cigarette smoke, for example, has been shown to release more than 7,000 chemicals into the air. “The plants might take up some of the VOCs,” Niri says, “but I don’t think they will be able to get rid of all the chemicals and the smell of cigarette.”

Chemical Regulation Gets a Major Overhaul



Chemicals in household products today are commonly considered “innocent until proven guilty,” with barriers that make it difficult for the EPA to evaluate chemical safety. But legislation passed this year requires the EPA to consent to new chemicals before they enter the marketplace.

The legislation is the first substantial change to the Toxic Substances Control Act, known as TSCA, since Congress enacted the legislation 40 years ago. Business groups and environmental groups both agreed that the prior law was too weak and pushed for an overhaul.

Many environmental groups called the compromise legislation an improvement over existing law but said it falls short of expectations. The law does not explain how the EPA will fund its mandate to evaluate such a high volume of chemicals. And many fear that strong state protections could be preempted by weaker federal protections.

“The compromise version looks like a house of cards,” Leonardo Trasande, a New York University professor who studies environmental health, said after it passed Congress. “It has a very strong [set of] principles, but the implementation could leave less than the desired outcome.”

BPA Is Still Present in 60% of Cans in the U.S.



A new report from a group of nonprofits shows that many food cans on U.S. grocery-store shelves still contain the chemical Bisphenol A, known as BPA. BPA may cause hormone disruption—which is of particular concern for young children and pregnant women. In part thanks to campaigns by consumer advocates, food companies said they would remove the chemicals from cans, but more than two thirds of cans tested, including products by some of America’s largest food companies, still contain the chemical, according to the report.

“This is shocking to us, because we’ve been hearing for years now that the canned food industry en masse was moving away from BPA,” says report co-author Janet Nudelman, director of program and policy at the advocacy group Breast Cancer Fund.

According to the report, all of the Campbell’s cans tested, 71% of those from Del Monte and 50% of sampled General Mills cans contained BPA. Amy’s Kitchen, Annie’s Homegrown, Hain Celestial Group and ConAgra have all transitioned away from BPA—and that was reflected in the test results as well; those tested in this study were free of BPA. The report says that some of the companies found to have BPA in their cans have previously made commitments to phase out the chemical.

HOLY COW!

Why the Water in the Olympic Diving Pool Turned Green



The water in the Rio Olympics diving pool turned from a crystal blue to a murky green during the Games due to a “proliferation of algae,” an official said.

The water at the aquatics center, which puzzled many competitors and Olympic viewers after it mysteriously transformed colors, was not dangerous to the athletes, Olympic organizers said in a statement.

“To ensure a high quality field of play is mandatory to the Rio 2016 organizing committee,” the statement said, according to the *New York Times*. “Water tests at Maria Lenk Aquatics Centre diving pool were conducted and found to be no risk to the athletes’ health.”

Officials said they were investigating the cause of the “situation.” Rio Olympics spokesman Mario Andrada told the Associated Press that the culprit behind the color change was “a proliferation of algae,” however. “This was because of heat and a lack of wind,” he said.

Tomorrow's Children



Every year, the State University of New York College of Environmental Science and Forestry in Syracuse announces a list of the top 10 new species. Above: a tiny amphibious isopod in Brazil, and, below, a flower on a new tree in Gabon, an eastern Santa Cruz tortoise from the Galápagos Islands in Ecuador, and a ruby seadragon in Australia.





Credits



Cosmonaut Oleg Kononenko snapped this shot of Manhattan from the International Space Station.

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